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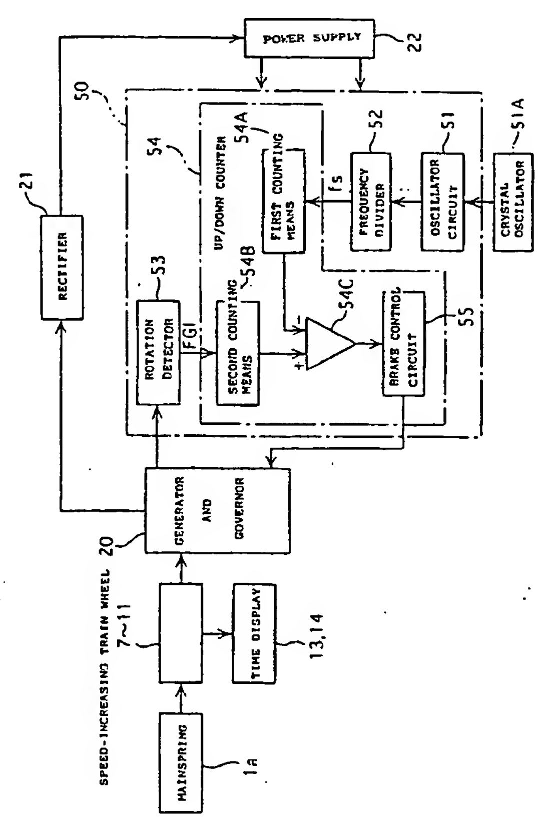
(54) **Electronically controlled, mechanical timepiece and control method for the same**

(57) The invention provides an electronically-controlled, mechanical timepiece that features fast governing control and low-cost design.

Specifically, an electronically-controlled, mechanical timepiece includes a generator 20 that converts mechanical energy transmitted from a mainspring la via a train wheel to feed electric energy, a hand connected to the train wheel, and rotation control means 50, driven by electric energy, for controlling the rotation period of the generator 20. The rotation control means 50 includes a rotation detector 53 for outputting a rotation signal FG1 of the generator 20, reference signal generating means for generating a reference signal fs, first counting means 54A and second counting means 54B for generating the reference signal fs and the rotation signal FG1, and a brake control circuit 55 for applying a brake on the generator 20 when a first count is smaller than a second count, and for applying no brake on the generator 20 when the first count is larger than the second count.

[FIG. 4]



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Description

[0001] The present invention r lates to an electronically-controlled, mechanical timepiece and a control method for the timepiece, in which mechanical energy in a mechanical energy source such as a mainspring is converted into electric energy by a generator, rotation control means is driven by the electric energy to control the rotation period of the generator, and a hand attached to a train wheel is thus accurately driven.

[0002] Japanese Examined Patent Publication No. 7-119812 and Japanese Unexamined Patent Publication No. 8-50186 disclose electronically-controlled, mechanical timepiecees that present accurate time by driving accurately hands attached onto train wheels. In such watches, a mainspring, when unwound, releases mechanical energy, which is converted into electric energy by a generator. The electric energy is then used to drive rotation control means so that a current flowing through a coil of the generator is controlled.

[0003] The watch disclosed in Japanese Examined Patent Publication No. 7-119812 features two angular ranges: an angular range in which a brake is turned off each time a rotor makes every turn, namely, for each period of a reference signal to heighten the rotational sp ed of a rotor so that generated power is increased, and an angular range in which the rotor is turned at a low speed with the brake applied. The efficiency in power generation is increased during a high-speed rotation to compensate for a drop in power generation taking place during the braking period.

[0004] In the watch disclosed in Japanese Unexamined Patent Publication No. 8-50186, a reference pulse and a measurement pulse detected in the course of rotation of a rotor are counted. The numbers of reference puls s and measurement pulses are compared with each other. In a first state in which the number of reference pulses is smaller than the number of measurement pulses, control means generates a brake signal for brake control, the width of which is determined by the measurement pulse.

[0005] In either electronically-controlled, mechanical timepiece, torque (mechanical energy) a mainspring applies onto a generator is set such that a hand is turned at a speed faster than a reference speed, and the rotational speed of the hand is adjusted by applying a brake through rotation control means.

[0006] The watch disclosed in Japanese Examined Patent Publication No. 7-119812 performs brake on control and brake off control for each rotation of the rotor, namely, every reference signal. With the generator on its initial startup or largely out of control, the rotational control amount of the rotor cannot be set to be large enough every reference signal. The watch thus needs a long time before reaching its normal control state with slow response.

[0007] In the watch disclosed in Japanese Unexamined Patent Publication No. 8-50186, the pulse width of the brake signal generated each reference signal is constant. Even with the watch largely out of control, the amount of braking for each reference signal remains constant. The watch thus needs a long time before reaching its normal control state with slow response.

[0008] Control means for generating brake signal having a pulse width determined in response to the measurement pulse is additionally required besides a circuit for detecting first and second states by comparing the counts of the reference pulses and measurement pulses. Such an arrangement requires a complicated construction, pushing up the cost of the watch.

[0009] A first object of the present invention is to provide an electronically-controlled, mechanical timepiece that features a high response in speed control and low cost design and to provide the control method of the watch.

[0010] In .the electronically-controlled, mechanical timepiece, when torque of the generator becomes insufficient with the mainspring unwound and its spring force weakened, the number of revolutions of the generator drops, lowering the speed of a hand, and continuously losing time for a long period of time.

[0011] Since the hand continuously moves even at a slow speed in this case, a user may glance at the watch and may be under the mistaken impression that the watch works correctly, even if the watch presents an incorrect time.

[0012] A second object of the present invention is to provide an electronically-controlled, mechanical timepiece that alerts the user to slow time to prevent the user from using the watch with a lost time.

[0013] According to a first aspect of the present invention, an electronically-controlled, mechanical timepiece preferably comprises a mechanical energy source, a generator, connected to the mechanical energy source via a train wheel and driven by the mechanical energy source, for generating induced power to feed electric energy, a hand connected to the train wheel, rotation control means, driven by the electric energy, for controlling the rotation period of the generator, wherein the rotation control means comprises rotation detecting means for detecting the rotation period of the generator and for outputting a rotation signal corresponding to the rotation period, reference signal generating means for generating a reference signal based on a signal from a time reference source, first counting means for counting the reference signal from the reference signal generating means, second counting means for counting the rotation signal from the rotation detecting means, and brake control means which controls the generator so that the generator is braked when a first count provided by the first counting means is smaller than a second count provided by the second counting means and is not braked when the first count is equal to or greater than the second count.

[0014] The electronically-controlled, mechanical timepiece of the present invention drives the hand and

the generator with the mechanical energy source such as a mainspring and applies a brake on the generator through the brake control means of the rotation control means, thereby governing the number of revolutions of a rotor, namely, the hand.

[0015] The first counting means counts the reference signal from the reference signal generating means, the second counting means counts the rotation signal from the rotation detecting means to compare the first count and the second count, and the brake control means brakes the generator when the first count is smaller than the s cond count, and does not brake the generator when the first count is equal to or greater than the second count. In this way, the rotation control means of the generator governs the rotational speed of the generator.

[0016] When the first count remains smaller than the second count, namely, when the torque in the mechanical energy source such as the mainspring is large enough to rotate the generator, a brake is continuously applied until there is no difference between the two counts. The watch thus governs the rotation of the generator, quickly allowing the generator to reach a normal rotational speed under fast response control.

[0017] Since the brake control is performed by simply comparing the two counts, simple-construction rotation control means works, resulting in a cost reduction of the watch.

[0018] The brake control means preferably comprises comparing means for comparing the first count with the second count.

[0019] The first counting means, the second counting means and the comparing means are preferably constructed of an up/down counter. The use of the up/down counter permits counting while performing a comparison action at the same time. With this arrangement, the construction of each means is simplified, and the difference between counts is easily determined.

[0020] The up/down counter preferably counts at least three values.

[0021] An up/down counter of 2 bits or more may be used to perform counting at multi levels and to store counts. With this arrangement, not only a determination is made of whether the second count leads or lags the first count as a reference, but also cumulative quantities of lead and lag therebetween are stored. As a result, the cumulative error may be corrected.

[0022] The rotation control means, when initially supplied with electric energy by the generator, may keep the brake control means in an inoperative state until the number of revolutions of the generator reaches a predetermined value, for example, until the rotation signal is detected a predetermined number of times.

[0023] When electric energy is initially fed by the generator, namely, at the startup of the generator, the brake control means remains in an inoperative state, applying no brake, until the generator is driven at a predetermined number of revolutions, and a priority is placed on power generation. In this way, a voltage capable of driving the rotation control means is quickly obtained, and the reliability of control is heightened.

[0024] A particular threshold may be set in the up/down counter so that the braking of the generator is initiated or released when the count of the up/down counter crosses the threshold.

[0025] With this arrangement, the brake control is performed by simply comparing the two counts, simple-construction rotation control means works, resulting in a cost reduction of the watch.

[0026] The up/down counter is preferably set within a range of ± 1 of the threshold when the generator initially feeds electric energy to the up/down counter.

[0027] With this arrangement, a small difference between a preset value of the up/down counter and the threshold permits a brake to be applied quickly after the start of the rotation control. The watch thus governs the rotation of the generator, quickly allowing the generator to reach a normal rotational speed under fast response control.

[0028] The up/down counter counts and holds at least three values. A count range extending over a plurality of counts, within which brake control is performed is preferably set to be narrower than a count range within which no brake is applied.

[0029] With this arrangement, a cumulative compensation range where the rotation period of the rotor is longer than the reference period (in a state of brake release) is widened, and a cumulative error is efficiently corrected for. Specifically, when a brake is applied, the rotation period of the rotor is easily set close to the reference period and the cumulative error is small and a compensation range for it is advantageously small. When no brake is applied, mechanical variations in the movement of the watch may increase the cumulative error. With the cumulative compensation range in the brake released state set to be wide, the cumulative error is stored and then reliably corrected.

[0030] According to a second aspect of the present invention, the electronically-controlled, mechanical timepiece comprises a mechanical energy source, a train wheel driven by the mechanical energy source, a generator, driven by mechanical energy from said mechanical energy source through the train wheel, for feeding electric energy, a hand connected to the train wheel, rotation control means, driven by the electric energy, for controlling the rotation period of the generator, wherein the rotation control means comprises rotation detecting means for detecting the rotation period of the generator and for outputting a rotation signal corresponding to the rotation period, reference signal generating means for generating a reference signal based on a signal from a time reference source, an up/down counter which receives one of the rotation signal and the reference signal as an up count input signal and the other of the rotation signal and the reference signal as a down count input signal, and brake control means which controls the generator by applying a governing brake on the generator

when the rotation period of the generator gets shorter, causing the count of the up/down counter to reach a first set value, and by applying a hand stopping brake on the generator when the rotation period of the generator gets longer than a reference period with no brake applied on the generator, causing the count of the up/down counter to reach a second set value.

[0031] The electronically-controlled, mechanical timepiece of the present invention drives the hand and the generator with the mechanical energy source such as a mainspring and applies a brake on the generator through the brake control means of the rotation control means, thereby governing the number of revolutions of a rotor, namely, the hand.

[0032] When the up/down counter, for counting the reference signal from the reference signal generating means and the rotation signal from the rotation detecting means, reaches the first set value, mechanical energy from the mechanical energy source such as the mainspring is large enough to shorten the rotation period of the generator shorter than the reference signal period. The rotation control means of the generator thus applies a governing brake on the generator.

[0033] When mechanical energy from the mechanical energy source drops to a state in which no brake is applied to the generator (the up/down counter gives any count other than the first set value), the rotation period of the generator becomes longer than the reference period and the up/down counter reaches the second set value. The rotation control means of the generator then applies a hand stopping brake on the generator.

[0034] Specifically, the hand stopping brake control is to apply continuously a brake on the generator to stop the hand or drive the hand at a very slow speed.

[0035] With the hand motionless or moving at a slow speed, the user recognizes it and is alerted to slow time when the user looks at the hand on the watch to check time. This arrangement helps the user avoid using the watch with no knowledge of slow time, and urges the user to tighten the mainspring, giving a chance to the user to put the electronically-controlled. mechanical timepiece back into the normal operating condition.

[0036] The brake control means includes brake releasing means for releasing the hand stopping brake, and the hand stopping brake, once initiated, is continuously applied until the brake is released by the brake releasing means.

[0037] The brake control means includes the brake releasing means, and the hand stopping brake is continuously applied until the brake is released by the brake releasing means. Once the hand stopping brake control is activated, the motionless state is reliably maintained until the normal hand turning condition is recovered, for example, by tightening the mainspring.

[0038] The brake releasing means preferably releases the hand stopping brake in response to the operation of an external operational member, such as a crown or a dedicated button, by a user.

[0039] Recognizing the slow-turning or motionless hand, the user releases the brake using the external operation member. The hand stopping brake is maintained until the user recognizes such a hand and releases the brake. The watch reliably alerts the user to such abnormal state of the hand.

[0040] The external operational member is preferably a crown. When recognizing the slow-turning or motionless hand, the user turns the crown to tighten the mainspring. If the hand stopping brake control is designed to be released in response to the operation of the crown, the user is freed from a separate brake releasing operation using a dedicated button, for example. The ease of operation of the watch is thus improved.

[0041] Preferably, the brake releasing means includes a low-speed rotation detector for detecting the rotational speed of the generator when the rotational speed of the generator drops below a set value, and releases the hand stopping brake when the low-speed rotation detector circuit detects a rotational speed of the generator below the set value. The hand stopping brake may be released immediately when the low-speed rotation detector detects the rotational speed of the generator below the set value, or the hand stopping brake may be released only when the generator keeps its rotational speed lower than the set value for a predetermined duration of time.

[0042] The hand stopping brake control is performed when energy from the mechanical energy source drops causing the generator to rotate at a lower speed. If the rotational speed of the generator drops below the predetermined set value as a result of brake control, no rise in hand turning speed is thereafter expected even if the brake control is released. This arrangement alerts the user to an abnormal state of the hand, while releasing automatically the brake control. With the brake control already released, the user adjusts the watch for the correct time smoothly when noticing a slow-turning or motionless hand. The ease of operation is thus further promoted.

[0043] The brake releasing means preferably releases the hand stopping brake when a predetermined duration of time elapses from the moment the hand stopping brake was applied.

[0044] When a brake is applied for a predetermined duration (4 seconds, for example) with the generator rotating at a low speed, no rise in the hand turning speed is thereafter expected in practice even if the brake is automatically released. This arrangement alerts the user to a slow-turning or motionless hand, while releasing automatically the brake control. With the brake control already released, the user adjusts the watch for the correct time smoothly when noticing the slow-turning or motionless hand. The ease of operation is thus further promoted. The predetermined duration for braking is determined considering the mechanical load of the watch and the torque of the mainspring, and is typically 2 to 6 seconds.

[0045] The brake control means performs controlling which alternates between a predetermined duration of brake application and a predetermined duration of brake release, for a duration throughout which the count of the up/down counter stays on the second set value.

[0046] The hand stopping brake control alternates the brake on period and the brake off period (for example, 4 seconds of brake on and 4 seconds of brake off) rather than continuously applying brake. With this arrangement, the generator is allowed to operate for the brake off period while the user turns the crown to tighten the mainspring. As a result, the rotation signal is input to the up/down counter, causing it to be out of the second set value, and putting the watch to the normal hand control state. This arrangement eliminates the need for arranging the brake releasing means, resulting in a cost reduction of the watch.

[0047] The second set value may be equal to the first set value, and the governing brake by the brake control means and the hand stopping brake by the brake control means may be identical to each other.

[0048] Preferably, the up/down counter shifts to the maximum count when a down count input signal is further applied to the up/down counter when the up/down counter gives the minimum count, and shifts to the minimum count when an up count input signal is further applied to the up/down counter when the up/down counter gives the maximum count.

[0049] With the first and second set values being the same and the brake controls for the governing brake and the hand stopping brake being identical, the brake control for the governing brake and the brake control for the hand stopping brake may be performed by the same construction. The watch thus features a reduced component count, thus, a simplified construction and reduced cost.

[0050] The control method of an electronically-controlled, mechanical timepiece of the present invention which comprises a mechanical energy source, a generator, connected to the mechanical energy source via a train wheel and driven by the mechanical energy source, for generating induced power to feed electric energy, a hand connected to the train wheel, rotation control means, driven by the electric energy, for controlling the rotation period of the generator, comprises the steps of counting a reference signal based on a signal from a time reference source to determine a first count, counting a rotation signal that is output in accordance with the rotation period of the generator to determine a second count, and controlling the generator by applying a brake on the generator when the first count is smaller than the second count, and by not applying a brake on the generator when the first count is equal to or greater than the second count.

[0051] According to this control method, when the first count remains smaller than the second count, namely, when the torque of the mechanical energy source such as the mainspring is large enough to advance the generator in rotation, a brake is continuously applied until there is no difference between the counts. The watch thus governs the rotation of the generator, allowing the generator to reach quickly a normal rotational speed under fast response control.

[0052] The control method of an electronically-controlled, mechanical timepiece of the present invention which comprises a mechanical energy source, a generator, connected to the mechanical energy source via a train wheel and driven by the mechanical energy source, for generating induced power to feed electric energy, a hand connected to the train wheel, rotation control means, driven by the electric energy, for controlling the rotation period of the generator, comprises the steps of inputting, to an up/down counter, a reference signal based on a signal from a time reference source and a rotation signal that is output in accordance with the rotation period of the generator, with one of the reference signal and the rotation signal as an up count input signal and the other of the reference signal and the rotation signal as a down count input signal, applying a brake on the generator when the up/down counter reaches a predetermined value, and not applying a brake on the generator when the up/down counter gives a value other than the predetermined value.

[0053] According to this control method, when the count of the up/down counter reaches the predetermined value, namely, when the torque of the mechanical energy source such as the mainspring is large enough to advance the generator in rotation, a brake is continuously applied until there is no difference between the counts. The watch thus governs the rotation of the generator, allowing the generator to reach quickly a normal rotational speed under fast response control.

[0054] The use of the up/down counter permits counting while performing a comparison action at the same time. With this arrangement, the construction of each means is simplified, and the difference between counts is easily determined.

[0055] The control method of an electronically-controlled, mechanical timepiece of the present invention which comprises a mechanical energy source, a generator, connected to the mechanical energy source via a train wheel and driven by the mechanical energy source, for generating induced power to feed electric energy, a hand connected to the train wheel, rotation control means, driven by the electric energy, for controlling the rotation period of the generator, comprises the steps of inputting, to an up/down counter, a reference signal based on a signal from a time reference source and a rotation signal that is output in accordance with the rotation period of the generator, with one of the reference signal and the rotation signal as an up count input signal and the other of the reference signal and the rotation signal as a down count input signal, controlling the generator by applying a governing brake on the generator when the rotation period of the generator gets shorter, causing the count of the up/down counter to reach a first

set value, and by applying a hand stopping brake on the generator when the rotation period of the generator gets longer than a reference period with no brake applied on the generator, causing the count of the up/down counter to reach a second set value.

[0056] When mechanical energy from the mechanical energy source drops to a state in which no brake is applied to the generator (the up/down counter gives any count other than the first set value), the rotation period of the generator becomes longer than the reference period and the up/down counter reaches the second set value. The rotation control means of the generator then applies a hand stopping brake on the generator.

[0057] With the hand motionless or moving at a slow speed, the user recognizes it and is alerted to slow time when the user looks at the hand on the watch to check time. This arrangement helps the user avoid using the watch with no knowledge of slow time, and urges the user to tighten the mainspring, giving a chance to the user to put the electronically-controlled, mechanical timepiece back into the normal operating condition. Embodiments of the present invention will now be described by way of further example only and with reference to the accompanying drawings, in which:

[0058] FIG. 1 is a plan view showing the electronically-controlled, mechanical timepiece of a first embodiment of the present invention.

[0059] FIG. 2 is a cross-sectional view of a major portion of the watch shown in FIG. 1.

[0060] FIG. 3 is a cross-sectional view of a major portion of the watch shown in FIG. 1.

[0061] FIG. 4 is a block diagram showing the watch of the first embodiment of the present invention.

[0062] FIG. 5 is a schematic diagram of the watch of the first embodiment of the present invention.

[0063] FIG. 6 is a timing diagram of the operation of the first embodiment.

[0064] FIG. 7 is a timing diagram of the operation of the first embodiment.

[0065] FIG. 8 is a timing diagram of the operation of the first embodiment.

[0066] FIG. 9 is a flow diagram showing the control method of the first embodiment.

[0067] FIG. 10 is a schematic diagram showing a second embodiment of the present invention.

[0068] FIG. 11 is a schematic diagram showing a third embodiment of the present invention.

[0069] FIG. 12 is a timing diagram of the operation of the third embodiment of the present invention.

[0070] FIG. 13 is a timing diagram of the operation of the third embodiment of the present invention.

[0071] FIG. 14 is a timing diagram of the operation of the third embodiment of the present invention.

[0072] FIG. 15 is a flow diagram showing the control method of the third embodiment of the present invention.

[0073] FIG. 16 is a block diagram showing a major portion of the electronically-controlled, mechanical timepiece of a fourth embodiment of the present invention.

[0074] FIG. 17 is a schematic diagram of the electronically-controlled, mechanical timepiece of the fourth embodiment of the present invention.

[0075] FIG. 18 is a timing diagram of the brake control of the fourth embodiment of the present invention.

[0076] FIG. 19 is a timing diagram of the brake control of the fourth embodiment of the present invention.

[0077] FIG. 20 is a flow diagram of the control method of the fourth embodiment of the present invention.

[0078] FIG. 21 is a flow diagram of the control method of the fourth embodiment of the present invention.

[0079] FIG. 22 is a schematic diagram of the electronically-controlled, mechanical timepiece of a fifth embodiment of the present invention.

[0080] FIG. 23 is a timing diagram of the operation of the fifth embodiment of the present invention.

[0081] FIG. 24 is a timing diagram of the operation of the fifth embodiment of the present invention.

[0082] FIG. 25 is a timing diagram of the operation of the fifth embodiment of the present invention.

[0083] FIG. 26 is a waveform diagram of a generator of the fifth embodiment of the present invention.

[0084] FIG. 27 is a flow diagram of the control method of the fifth embodiment.

[0085] FIG. 28 is a schematic diagram of the electronically-controlled, mechanical timepiece of a sixth embodiment of the present invention.

[0086] Referring to the drawings, the embodiments of the present invention are now discussed.

[0087] FIG. 1 is a plan showing a major portion of electronically-controlled, mechanical timepiece of a first embodiment of the present invention. FIGS. 2 and 3 are cross-sectional views of the watch.

[0088] The electronically-controlled, mechanical timepiece comprises a movement barrel 1 including a mainspring la, a barrel wheel 1b, a barrel arbor 1c, and a barrel cover 1d. The mainspring 1a is supported with its outer end anchored at the barrel wheel 1b and its inner end anchored at the barrel arbor 1c. The barrel arbor 1c is supported by a main plate 2 and a train wheel support 3, and is rigidly secured to a ratchet wheel 4 by a ratchet wheel screw 5 so that both the barrel arbor 1c and the ratchet wheel 4 are integrally rotated.

[0089] The ratchet wheel 4 is in mesh with a detent 6 so that it is rotated clockwise but is not rotated counterclockwise. The method of turning the ratchet wheel 4 clockwise to tighten the mainspring la is identical to the mechanism of self-winding or manual winding of a mechanical timepiece, and is not discussed here. The rotation of the barrel wheel 1b is stepped up in speed by 7 times and transmitted to a second wheel and pinion 7, and thereafter sequentially stepped up by 6.4 times there and transmitted to a third wheel and pinion 8, stepped up by 9.375 times there and transmitted to a fourth wheel and pinion 9, stepped up by 3 times there and transmitted to a fifth wheel and pinion 10, stepped up by 10 times there and transmitted to a sixth wheel

and pinion 11, stepped up by 10 times there and transmitted to a rotor 12. Through these step-up train wheels 7 through 11, the rotational speed is increased by 126,000 times.

[0090] A minute hand 13 for indicating time is attached to the cannon pinion 7a of the second wheel and pinion 7 and a second hand 14 for indicating time is attached to the fourth wheel and pinion 9. To rotate the second wheel and pinion 7 at 1 rph and fourth wheel and pinion 9 at 1 rmp, the rotor 12 may be controlled to rotate at 5 rps. The barrel wheel 1b then rotates at 1/7 rph.

[0091] The electronically-controlled, mechanical timepiece includes a generator 20 constructed of the rotor 12, a stator 15 and a coil block 16 therein. The rotor 12 includes a rotor magnet 12a, a rotor pinion 12b, and a rotor flywheel 12c. The rotor flywheel 12c reduces variations in the number of revolutions of the rotor 12 against variations in driving torque of the movement barrel 1. The stator 15 includes a stator body 15a around which a stator coil 15b of 40,000 turns is wound.

[0092] The coil block 16 includes a coil core 16a around which a coil 16b of 110,000 turns is wound. The stator body 15a and the coil core 16a are made of PC Permalloy or the like. The stator coil 15b and the coil 16b are connected in series so that the sum of the voltages across these coils is output.

[0093] Referring to FIGS. 4 and 5, the control circuit of the electronically-controlled, mechanical timepiece is now discussed. FIG. 4 is a block diagram showing the electronically-controlled, mechanical timepiece of the first embodiment of the present invention. FIG. 5 is a schematic diagram of the watch.

[0094] An alternating current output from the generator 20 is stepped up and rectified through a rectifier 21 comprised of a step-up rectifier, a full-wave rectifier, a half-wave rectifier, a transistor rectifier or the like, and is fed to a capacitor 22 as a power supply.

[0095] A brake circuit 23 including a transistor 23B as a switching element is connected to the generator 20. By controlling the brake circuit 23, the generator 20 is governed. The brake circuit 23 is preferably designed taking into consideration the parasitic diode of the transistor 23B.

[0096] Rotation control means 50 includes an oscillator circuit 51, a frequency divider 52, a rotation detector 53 for detecting the rotation of the rotor 12, first counting means 54A, second counting means 54B, comparing means 54C, and a brake control circuit 55. In this embodiment, the first counting means 54A, second counting means 54B, comparing means 54C and brake control circuit 55 are constructed of an up/down counter.

[0097] The oscillator circuit 51 outputs an oscillation signal (32768 Hz) from a crystal oscillator 51A as a time reference source, and the oscillation signal is frequency-divided to a signal having a predetermined period by the frequency divider 52 of 12 stages of flip-flops. The divided signal is output to the first counting means 54A as an 8-Hz reference signal fs. The oscillator circuit 51 and the frequency divider 52 form reference signal genrating means 56.

[0098] The rotation detector 53 includes a waveform shaper 61 connected to the generator 20 and a monostable multivibrator 62. The waveform shaper 61 includes an amplifier and a comparator, and converts a sinusoidal wave signal into a rectangular wave signal. The monostable multivibrator 62 works as a bandpass filter that passes pulses having a period longer than a certain value, and outputs a rotation signal FG1 with noise filtered out therefrom.

[0099] The rotation signal FG1 from the rotation detector 53 and the reference signal fs from the frequency divider 52 are respectively input to an up count input and a down count input of an up/down counter 54 via a synchronizing circuit 70 as shown in FIG. 5.

[0100] The synchronizing circuit 70 includes four flip-flops 71, two AND gates 72, and two NAND gates 73, and makes the rotation signal FG1 synchronized with the reference signal fs (8 Hz) using the output (1024 Hz) from the fifth stage of the frequency divider 52 and the output (512 Hz) from the sixth stage of the frequency divider 52 and adjusts the pulses of these signals so that they are not concurrently output.

[0101] The up/down counter 54 is a 4-bit counter. The up/down counter 54 receives, at its up count input, a signal based on the rotation signal FG from the synchronizing circuit 70, and receives, at its down count input, a signal based on the reference signal fs from the synchronizing circuit 70. With this arrangement, the up/down counter 54 concurrently counts the reference signal fs, the rotation signal FG1 (at the first counting means 54A and the second counting means 54B) and the difference between the two counts (at the comparing means 54C).

[0102] The up/down counter 54 is provided with four input terminals preset terminals) A through D. Terminals A through C are pulled up to a high level, setting the initial value preset value) of the up/down counter 54 at "7".

[0103] A startup and initializing circuit 90 is connected to the load input of the up/down counter 54. The startup and initializing circuit 90 includes an initializing circuit 91, connected to the capacitor 22, for outputting a system reset signal SR when power is initially fed to the capacitor 22, a frequency divider 92, reset by the system reset signal RS, for counting a predetermined number of pulses of rotation signal FG1, a flip-flop 93, reset by the system reset signal SR, for receiving the clock signal from the frequency divider 92.

[0104] The frequency divider 92, formed of 4 stages of flip-flops, outputs a high-level signal when it receives 16 pulses of the rotation signal FG1. When receiving 16 pulses of the rotation signal FG1 from the input of the system reset signal SR, the flip-flop 93 outputs a high-level signal to the load input of the up/down counter 54.

[0105] The up/down counter 54 does not accept the

up and down inputs for a constant duration of time from the output of the system reset signal SR to the transition of the load input to a high level, the up/down counter 54 is maintained at the count of "7".

[0106] The up/down counter 54 is provided with 4-bit outputs QA-QD. The fourth bit output QD outputs a low-level signal when the count is 7 or lower, and outputs a high-level signal when the count is 8 or higher. The output QD is connected to the gate of the N-channel transistor 23B in the brake circuit 23 connected in parallel with the generator 20. When the output QD gives a high-level signal to the gate of the transistor 23B, the transistor 23B is turned on, shorting the generator 20 and thereby applying a brake on it.

[0107] When the output QD gives a low-level signal, the gate voltage of the transistor 23B drops, turning off the transistor 23B. The generator 20 is not braked. Since the brake circuit 23 is controlled by the output QD of the up/down counter 54, the up/down counter 54 also works as the brake control circuit 55.

[0108] The operation of this embodiment is now discussed referring to timing diagrams shown in FIGS. 6 through 8 and a flow diagram shown in FIG. 9.

[0109] When the generator 20 starts working, the system reset signal SR is output in Step 1 (or S1, hereinafter Step is simply referred to as S). After a predetermined time elapse, the startup and initializing circuit 90 inputs a high-level signal to the load input of the up/down counter 54 (S2). As shown in FIG. 6, the up/down counter 54 counts the up count input signal based on the rotation signal FG1 and the down count input signal based on the reference signal fs (S3). The synchronizing circuit 70 adjusts these signals so that they are not concurrently input to the up/down counter 54.

[0110] The preset count "7" is changed to "8" when an up count input signal is fed. The output QD gives a high-level signal to the transistor 23B in the brake circuit 23. The brake on control is performed to apply a brake on the generator 20 (S4 and S5).

[0111] If a down count input signal is fed, the count goes back to "7", the output QD outputs a low-level signal. The brake off control is performed to apply no brake on the generator 20 (S4 and S6).

[0112] When the torque of the mainspring la becomes large enough to rotate the generator 20 at a high rotational speed, an up count input signal is further input even after the count is incremented to "8". In such a case, the count becomes "9", and the output QD remains at a high level, leaving a brake applied. With the brake continuously applied, the rotational speed of the generator 20 drops. If the reference signal fs (the down count input signal) is input twice before the entry of the rotation signal FG1, the count drops to "8", and to "7". At the moment the count drops to "7", the brake is released.

[0113] In such a brake control, the generator 20 reaches a set rotational speed, and the up count input signal and the down count input signal are alternately input to the up/down counter 54, causing the count to alternate between "8" and "7" in a locked state as shown in FIG. 7. In response to the count, the brake on and brake off are alternately repeated.

[0114] The mainspring la is unwound, outputting a smaller torque, and the brake on time is gradually shortened as shown in FIG. 8. The rotational speed of the generator 20 becomes close to the reference speed even with no brake applied.

[0115] With no brake applied at all, the down count input signal is more frequently input. The count drops to a value of "6" or smaller, and the torque of the mainspring la is regarded as lowered. The hand is thus motionless or left moving at a very slow speed. A buzzer may be sounded, or a light may be lit to urge the user to tighten the mainspring 1a.

[0116] This embodiment has the following advantages.

(1) The up count input signal based on the rotation signal FG1 and the down count input signal based on the reference signal fs are input to the up/down counter 54. When the count of the FG1 (up count input signal) is greater than the count of the reference signal fs (down count input signal) (namely, when the count is "8" or greater with the preset count at "7" in the up/down counter 54), the brake circuit 23 continuously applies a brake on the generator 20. When the count of the rotation signal FG1 is equal to or smaller than the count of the reference signal fs (when the count is "7" or smaller), the generator 20 is released from braking. With this arrangement, the generator 20 quickly becomes close to the reference speed under fast response rotation control even when the rotational speed of the generator 20 substantially deviates from the reference speed, for example, at the startup.

(2) Since the brake control depends on whether the count is "7" or smaller, or "8" or greater, there is no need for setting separately a braking time. Simple-construction rotation control means 50 works, reducing component cost and manufacturing cost, and thereby resulting in a low-cost electronically-controlled, mechanical timepiece.

(3) The duration of the count "8", namely, the braking time, is automatically adjusted because the timing of the up count input signal is varied depending on the rotational speed of the generator 20. For this reason, fast and stable response control is carried out, particularly, in the locked state in which the up count input signal and the down count input signal are alternately input.

(4) Counting and comparing the count outputs (for the difference therebetween) are concurrently performed since the up/down counter 54 is used as the counting means. This arrangement easily results in the difference between the counts and is simple construction, compared with the construction in

which the first counting means 54A and second counting means 54B ar separately arranged with the comparing means 54C attached for comparing the count outputs from them.

(5) The 4-bit up/down counter 54 counts up to 16. When the up count input signal is repeatedly input, the inputs are cumulatively counted. Within a set range, namely, a range over which the count rises up "15" or falls down to "0" with the up count input signal or the down count input signal successively input, a cumulative error is corrected. Even if the rotational speed of the generator 20 substantially deviates from the reference speed, the generator 20 reverts back to the reference speed with the cumulative error reliably corrected, though it takes time for the up/down counter 54 to reach the locked state. In the long run, this control proves effective in maintaining an accurate hand turning.

(6) The startup and initializing circuit 90 performs no brake control at the startup of the generator 20 with no brake applied thereon. Thus, charging the capacitor 22 has a priority. As a result, the rotation control means 50, driven by the capacitor 22, smoothly and reliably works, heightening the reliability of subsequent rotation control.

[0117] Referring to FIG. 10, a second embodiment of the present invention is now discussed. Components identical or equivalent to those described in connection with the first embodiment are designated with the same reference numerals.

[0118] In the second embodiment, a line decoder 100 is connected to the output side of the up/down counter 54. Outputs Y8-Y15, respectively corresponding to counts "8"-"15" of the up/down counter 54, are input to the transistor 23B in the brake circuit 23.

[0119] The line decoder 100 outputs a low level signal at one output, with the remaining 15 outputs at a high level. Outputs Y8-Y15 are connected to a NAND gate 101. When one of these outputs is selected, namely, when the count of the up/down counter 54 is one of "8" through "15", a high-level signal is input to the gate of the transistor 23B. When the count is "7" or smaller, a low-level signal is input to the gate of the transistor 23B.

[0120] The outputs Y0 and Y15 of the line decoder 100 are input to respective NAND gates 102 to which the outputs of the synchronizing circuit 70 are also applied. Now suppose that the up count input signal is fed a plural number of times causing the count to rise to "15" and a low-level signal to be output from the Y15. Then, if a further up count input signal is input to the NAND gate 102, the input is canceled, and no further up count input signal afterward is input to the up/down counter 54. In this way, the count is prevented from shifting "15" to "0", or shifting from "0" to "15". In the second embodiment, the initial value of th up/down counter 54 is set to count "8".

[0121] The second embodiment has the same advantages as those of the first embodiment, as stated in (1)-(6) in connection with the first embodiment. The second embodiment additionally presents the following advantage.

(7) The line decoder 100 is provided so that the outputs Y0-Y15, corresponding to the counts "0"-"15", are fed back to the NAND gates 102. The count is prevented from shifting "15" to "0", or shifting from "0" to "15", even if the up count input signal or the down count input signal is input in succession. When a cumulative error becomes large in magnitude, a determination of whether the error is in the direction of lead or lag is quickly made, and an erratic control is avoided.

[0122] A third embodiment of the present invention is now discussed referring to FIGS. 11-15. As shown in FIG. 11, the generator 20 is provided with a brake circuit 120 including a rectifier 105. The brake circuit 120 includes switches 121 and 122 for shorting output terminals MG1 and MG2 of the generator 20 for braking. In the third embodiment, the switches 121 and 122 are P-channel transistors.

[0123] The voltage doubler rectifier 105 is constructed of a capacitor 123 connected to the generator 20, diodes 124, 125, and switching transistors 126 and 127.

[0124] As in the preceding embodiments, the brake circuit 120 is controlled by the rotation control means 50 which is operated from power supplied by the power supply (capacitor) 22.

[0125] The brake control circuit 55 includes the up/down counter 54, the synchronizing circuit 70 and a chopper signal generator 80.

[0126] The up/down counter 54 receives, at its up count input, the rotation signal FG1 of the rotation detector 53 and, at its down count input, the reference signal fs from the frequency divider 52, via the synchronizing circuit 70.

[0127] The up/down counter 54 is a 4-bit counter as in the preceding embodiments. Out of the four data input terminals preset terminals) A-D of the up/down counter 54, a high-level is input to terminals A, B and D. The initial value preset value) of the up/down counter 54 is set to "11".

[0128] The up/down counter 54 accepts no up/down count input signals until the load input, namely, the system reset SR, turns low. The up/down counter 54 remains on the count of "11" as shown in FIG. 12.

[0129] The up/down counter 54 has 4 bit outputs of QA-QD. When the count is "12" or higher, both third bit output QC and fourth bit output QD gives a high-level signal. When the count is "11" or lower, at least one of the third bit output QC and the fourth bit output QD gives a low-level signal.

[0130] The output LBS of an AND gate 110, to which outputs QC and QD are input, is a high-level signal when the up/down counter 54 gives the count of "12" or higher,

and is a low-level signal when the up/down counter 54 gives the count of "11" or lower. The output LBS is connected to the chopper signal generator 80.

[0131] The outputs of a NAND gate 111 and an OR gate 112, each receiving the outputs QA-QD, are input to each of the NAND gates 102, to which the outputs of the synchronizing circuit 70 are also input. When the up count input signal is repeatedly input causing the count to reach "15", the NAND gate 111 outputs a low-level signal. Then, if a further up count input signal is input to the NAND gate 102, the input is canceled, and no further up count input signal afterward is input to the up/down counter 54. Similarly, when the count reaches "0", the OR gate 112 outputs a low-level signal, and a further down count input signal is canceled. As in the second embodiment, the count is prevented from shifting "15" to "0", or shifting from "0" to "15".

[0132] The chopper signal generator 80 includes first chopper signal generating means 81, constructed of three AND gates 82-84, for outputting a first chopper signal CH1 based on the outputs Q5-Q8 of the frequency divider 52, second chopper signal generating means 85, constructed of two OR gates 86 and 87, for outputting a second chopper signal CH2 based on the outputs Q5-Q8 of the frequency divider 52, an AND gate 88 for receiving the output LBS of the up/down counter 54 and the output CH2 of the second chopper signal generating means 85, and a NOR gate 89 for receiving the output of the AND gate 88 and the output CH1 of the first chopper signal generating means 81.

[0133] The output CH3 of the NOR gate 89 in the chopper signal generator 80 is input to the gates of switches 121 and 122 constructed of P-channel transistors. When the CH3 is a low-level signal, the switches 121 and 122 are kept turned on, shorting the generator 20 for braking.

[0134] When the CH3 is a high-level signal, the switches 121 and 122 are kept turned off, applying no brake on the generator 20. The chopper signal from the output CH3 thus controls the generator 20 in choppering control.

[0135] The operation of the third embodiment is discussed referring to timing diagrams shown in FIGS. 12-13, an output waveform diagram shown in FIG. 14, and a flow diagram shown in FIG. 15.

[0136] When the generator 20 starts operating, causing the initializing circuit 91 to output a low-level system reset signal SR to the load input of the up/down counter 54 (S11), the up count input signal based on the rotation signal FG1 and the down count input signal based on the reference signal fs are input to the up/down counter 54 as shown in FIG. 12 (S12). These signals are adjusted through the synchronizing circuit 70 so that they are not concurrently input to the up/down counter 54.

[0137] When the up count input signal is input with the initial count of "11", the count is shifted to "12". The output LBS is driven high, and is output to the AND gate 88 in the chopper signal generator 80.

[0138] When the down count input signal is input, causing the count to return to "11", the output LBS is driven low.

[0139] In the chopper signal generator 80, the first chopper signal generating means 81 gives the output CH1 and the second chopper signal generating means 85 gives the output CH2, based on the outputs Q5-Q8 of the frequency divider 52.

[0140] When the up/down counter 54 outputs a low-level output LBS (with the count at "11" or lower), the output of the AND gate 88 is also at a low level. The output CH3 of the NOR gate 89 is a chopper signal, which is an inverted CH1, having a duty factor (the ratio of turn on time of the switch 121 to that of the switch 122) of a long high-level duration (brake off time) and a short low-level duration (brake on time). The brake on time of the reference period becomes short, and practically, no brake is applied to the generator 20. Specifically, the brake off control with a priority placed on power generation is performed (S13 and S15).

[0141] When the up/down counter 54 outputs a high-level output LBS (with the count at "12" or higher), the output of the AND gate 88 is also at a high level. The output CH3 of the NOR gate 89 is a chopper signal, which is an inverted CH2, having a duty factor of a long low-level duration (brake on time) and a short high-level duration (brake off time). The brake on time of the reference period becomes long, and the brake on control is performed to the generator 20. However, the brake off is repeated at regular intervals, permitting the chopper control, in which a reduction in generated power is controlled while braking torque is increased (S13 and S14).

[0142] When the torque of the mainspring la is large enough to rotate the generator 20 at a high rotational speed, a further up count input signal may be fed even after the up count signal raised the count to "12". In such a case, the count rises to "13", and the output LBS remains at a high level. The brake on control is thus performed in which a brake is applied while being turned off at regular intervals. With a brake applied, the rotational speed of the generator 20 drops. If the reference signal fs (the down count input signal) is input twice before the entry of the rotation signal FG1, the count drops to "12", and to "11". At the moment the count drops to "11", the brake off control is entered, releasing the brake.

[0143] In such a brake control, the generator 20 reaches a set rotational speed, and the up count input signal and the down count input signal are alternately input to the up/down counter 54, causing the count to alternate between "12" and "11" in a locked state as shown in FIG. 12. In response to the count, the brake on and brake off are alternately repeated. Specifically, in one reference period during which the rotor makes one revolution, the chopper signal having a large duty factor and the chopper signal having a small duty factor are fed to the switches 121 and 122 to perform the chop-

per control.

[0144] The mainspring la is unwound, outputting a smaller torque, and the brake on time is gradually shortened. The rotational speed of the generator 20 becomes close to the reference speed even with no brake applied.

[0145] With no brake applied at all, the down count input signal is more frequently input. The count drops to a value of "10" or smaller, and the torque of the mainspring la is regarded as lowered. The hand is thus motionless or left moving at a very slow speed. A buzzer may be sounded, or a light may be lit to urge the user to tighten the mainspring la.

[0146] While the up/down counter 54 outputs a high-level LBS signal, the brake on control is performed using the chopper signal having a large duty factor. While the up/down counter 54 outputs a low-level LBS signal, the brake off control is performed using the chopper signal having a small duty factor. Specifically, the up/down counter 54 as the brake control means switches between the brake on control and the brake off control.

[0147] In the third embodiment, during the low-level LBS signal, the duty factor of the CH3 chopper signal is 15:1 (high-level duration:low-level duration), namely, 1/16=0.0625. During the high-level LBS signal, the duty factor of the CH3 chopper signal is 1:15 (high-level duration:low-level duration), namely, 15/16=0.9375.

[0148] Referring to FIG. 14, the generator 20 outputs, across MG1 and MG2, an alternating current in accordance with the change in magnetic flux as shown in FIG. 14. Depending on the output LBS signal, the chopper signals CH3 at a constant frequency but different duty factors are fed to the switches 121 and 122. When the high-level LBS signal is output, namely, during the brake on control, the braking time in each chopper cycle is lengthened. The amount of braking increases, reducing the rotational speed of the generator 20. As the brake is applied, generated power is reduced, accordingly. However, energy accumulated during the braking is output when the chopper signal turns off the switches 121 and 122, and is used to step up the output voltage of the generator 20. In this way, a reduction in generated power during the braking is compensated for. The braking torque is thus increased while the reduction in generated power is restricted.

[0149] When the low-level LBS signal is output, namely, during the brake off control, the braking time in the chopper cycle is shortened, increasing the rotational speed of the generator 20. In this case, also, the chopper signal turns the switches 121 and 122 from on to off, and chopper voltage stepup results. The generated power is large compared with the generated power with no brake applied at all.

[0150] The alternating current output of the generator 20 is stepped up and rectified through the voltage doubler rectifier 105, and charges the power supply (capacitor) 22, which in turn drives the rotation control means 50.

[0151] The output LBS of the up/down counter 54 and the chopper signal CH3 are commonly based on the outputs Q5-Q8 and Q12 of the frequency divider 52. More specifically, the frequency of the chopper signal CH3 is an integer multiple of the frequency of the output LBS, and the change in signal level of the output LBS, namely, a switch timing between the brake on control and the brake off control, takes place in synchronization with the chopper signal CH3.

[0152] The third embodiment of the present invention has also the advantages (1)-(5) and (7) as in the preceding embodiments. The third embodiment additionally presents the following advantages.

(8) When the up/down counter 54 outputs the count of "12" or higher, namely, within a range of 4 counts from "12" to "15", a brake is applied. When the up/down counter 54 outputs the count of "11" or lower, namely, within a range of 12 counts from "0" to "11", no brake is applied. In other words, the range of brake application is set to be narrower than the range of brake release in the count range of the up/down counter 54. The cumulative correction range where the rotor rotation period is longer than the reference period is thus widened, permitting reliably the correction of the cumulative error that is likely to take place with no brake applied. The rotational speed of the generator 20 is thus allowed to revert back to the reference speed.

[0153] Specifically, when the count is "12" or higher, a large torque of the mainspring 1a reduces the possibility that transient factors such as mechanical variations give rise to the input of an up count input signal. With the brake applied, it is unlikely that 3 or 4 pulses of the up count input signal are consecutively input. The generator 20 is reliably controlled even if the range of brake application is set to be as narrow as a 4-count range. On the other hand, when no brake is applied, the torque of the mainspring la is typically lowered. A transient factor, such as mechanical variations and an impact exerted on the watch, may cause the down count input signal to be input consecutively a plural number of times.

[0154] In the third embodiment, a 12-count range is set for the range of brake release. Even when the down count input signal is input consecutively a plural number of times, the cumulative value is stored and used to correct reliably the cumulative error.

(9) Since two types of chopper signals CH3 having different duty factors are used to perform the brake on control and the brake off control, the magnitude of braking (braking torque) is increased without lowering the charging voltage (generated voltage). Since the chopper signal having a large duty factor is used for controlling, particularly during the brake on duration, the braking torque is increased while controlling a drop in the charging voltage. In this

way, the reliability of the watch is maintained while an efficient brake control is attained at the same time. A long operation time is thus permitted in the electronically-controlled, mechanical timepiece.

(10) Since the chopper signal having a small duty factor is used for the chopper control during the brake off control period, the charging voltage is increased during the brake off duration.

(11) The change in the output level of the output QD, namely, the switch timing between the brake on control and the brake off control, is synchronized with the transition of the chopper signal CH3 from on to off. Impulses having a high voltage component are regularly output in synchronization with the chopper signal CH3 of the generator 20. This output may be used as a watch error measurement pulse.

[0155] When the output LBS and the chopper signal CH3 are not synchronized with each other, the generator 20 generates a high voltage component at the change in the output LBS, independently from the constant period chopper signal CH3. For this reason, the "impulses" in the waveform of the output voltage from the generator 20 do not necessarily have a constant period, and are not appropriate for use as the watch error measurement pulse. However, if the synchronization is assured as in this embodiment, the impulses serve as the watch error measurement pulse.

[0156] A fourth embodiment of the present invention is now discussed. FIG. 16 is a block diagram of the electronically-controlled, mechanical timepiece of the fourth embodiment. FIG. 17 is a schematic diagram of the watch.

[0157] As in the first embodiment, the electronically-controlled, mechanical timepiece includes a mainspring la as a mechanical energy source, train wheels 7-11 for transmitting torque of the mainspring la to the generator 20, and hands (a minute hand and a second hand) coupled to the train wheels 7-11, for indicating the time.

[0158] The generator 20 is driven by the mainspring la via the train wheels 7-11, and generates an electromotive force to supply electric energy. An alternating current output from the generator 20 is rectified through a rectifier 21 comprised of a step-up rectifier, a full-wave rectifier, a half-wave rectifier, a transistor rectifier, or the like and is stepped up as required, and is fed to a power supply 22 including a capacitor and the like.

[0159] Referring to FIG. 17, a brake circuit 23, having a transistor 23A as a switching element and a diode 23C, is connected to the generator 20. By controlling the brake circuit 23 to short both terminals of the generator 20, the generator 20 is governed. In the brake circuit 23, the diode 23C has preferably a small forward voltage.

[0160] The brake circuit 23 is controlled by rotation control means 50 powered by the power supply (capacitor) 22.

[0161] Referring to FIG. 16, the rotation control means 50 includes an oscillator circuit 51, a rotation detector 53, brake control means 200, and up/down counter 54.

[0162] The oscillator circuit 51 outputs an oscillation signal (32768 Hz) from a crystal oscillator 51A as a time reference source, and the oscillation signal is frequency-divided to a signal having a predetermined period by the frequency divider 52 of 12 stages of flip-flops as shown in FIG. 17. The output Q12 of the twelfth stage of the frequency divider 52 is output as an 8-Hz reference signal fs. The oscillator circuit 51, crystal oscillator 51A and frequency divider 52 form reference signal generating means 56.

[0163] The rotation detector 53 includes a waveform shaper 61 connected to the generator 20. The waveform shaper 61 includes an amplifier, a comparator, a filter and the like, converts a sinusoidal wave signal into a rectangular wave signal, and then outputs rotation signal FG1 with noise removed therefrom.

[0164] The rotation signal FG1 from the rotation detector 53 and the reference signal fs from the reference signal generating means 56 are respectively input to an up count input and a down count input of an up/down counter 54 via a synchronizing circuit 70.

[0165] The synchronizing circuit 70 includes four flip-flops 71 and four AND gates 72, and makes the rotation signal FG1 synchronized with the reference signal fs (8 Hz) using the output Q5 (1024 Hz) from the fifth stage of the frequency divider 52 and the output Q6 (512 Hz) from the sixth stage of the frequency divider 52 and adjusts the pulses of these signals so that they are not concurrently output.

[0166] The up/down counter 54 is a 4-bit counter. The up/down counter 54 receives, at its up count input, a signal based on the rotation signal FG from the synchronizing circuit 70, and receives, at its down count input, a signal based on the reference signal fs from the synchronizing circuit 70. With this arrangement, the up/down counter 54 concurrently counts the reference signal fs, the rotation signal FG1 and the difference between the two counts.

[0167] The up/down counter 54 is provided with four input terminals preset terminals) A through D. Terminals A, B and D are pulled up to a high level, setting the initial value preset value) of the up/down counter 54 at "11".

[0168] Connected to the load input of the up/down counter 54 is an initializing circuit 91 which, connected to the power supply 22, outputs a system reset signal SR depending on the voltage of the power supply 22.

[0169] The up/down counter 54 does not accept the up and down inputs until the system reset signal SR is output, and the up/down counter 54 is thus maintained at the count of The up/down counter 54 gives 4 bit outputs QA-QD, which are fed to a line decoder 100.

[0170] The line decoder 100 has outputs Y0-Y15, corresponding to counts "0"-"15" of the up/down counter 54. The outputs Y0 and Y15 of the line decoder 100 are input to respective NAND gates 102 to which the outputs of the synchronizing circuit 70 are also applied. Now

suppose that the up count input signal is fed a plural number of times causing the count to rise to "15" and a low-level signal to be output from the Y15. Then, if a further up count input signal is input to the NAND gate 102, the input is canceled, and no further up count input signal afterward is input to the up/down counter 54. In this way, the count is prevented from shifting "15" to "0", or shifting from "0" to "15".

[0171] A NAND gate 211 as governing brake signal generating means 210 is connected to the outputs Y12-Y15 of the line decoder 100. One output selected from the outputs of the line decoder 100 may turn low with the remaining 15 outputs left high. Outputs Y12-Y15 are connected to the NAND gate 211. When one of these outputs is selected, namely, the count as the first set value at the up/down counter 54 is within a count range from "12" to "15", a high-level output is given as a brake signal BKS2. When the count is "11" or lower (other than the first set value), a low-level signal is output.

[0172] The brake signal BKS2 is input to a NOR gate 201, and a brake signal BKS3 output by the NOR gate 201 is input a P-channel transistor 23A. When the up/down counter 54 becomes the first set value ("12"-"15"), the brake signal BKS2 is driven high in level, while the brake signal BKS3 output by the NOR gate 201 is driven low in level. The transistor 23A is turned on, shorting the generator 20 for braking.

[0173] The output Y0 of the line decoder 100 is coupled to the CK input of a flip-flop 222 via an inverter 221.

[0174] Since the D input of the flip-flop 222 is constantly supplied with a high-level signal. the flip-flop 222 outputs a high-level signal at its Q output when the up/down counter 54 outputs the count "0" giving a low-level signal at the output Y0. Even when the up/down counter 54 give a value other than "0", for example, "1", the Q output of the flip-flop 222 remains at a high level until a signal enters the CLR input of the flip-flop 222 for clearance.

[0175] The output FBS of the flip-flop 222 is input to the NOR gate 201. When the up/down counter 54 gives the count "0", the output FBS of the flip-flop 222 becomes high in level, driving low the brake signal BKS3 at the NOR gate 201. The transistor 23A remains turned on, shorting the generator 20 for braking. The output FBS is kept high until the flip-flop 222 is cleared with a signal input to the CLR input. The generator 20 is thus continuously braked. The inverter 221 and flip-flop 222 form hand stopping brake signal generating means 220.

[0176] The brake releasing means 230 is connected to the CLR input of the flip-flop 222.

[0177] Brake releasing means 230 includes a low-speed rotation detector 231 which receives the rotation signal FG1 and outputs a high-level signal when detecting a rotational speed of the generator 20 below the set value, a normally-open switch 232 which outputs a high-level signal when closed by the operation of an external operational member such as a crown, and an OR gate 233 for receiving signals from the low-speed rotation detector 231 and switch 232 and the system reset signal SR.

[0178] The operation of the fourth embodiment is now discussed referring to timing diagrams shown in FIGS. 18 and 19, and flow diagrams shown in FIGS. 20 and 21.

[0179] When the generator 20 starts operating, causing the initializing circuit 91 to output a low-level system reset signal SR to the load input of the up/down counter 54 (S21), the up count input signal based on the rotation signal FG1 and the down count input signal based on the reference signal fs are input to the up/down counter 54 as shown in FIG. 18 (S22). These signals are adjusted through the synchronizing circuit 70 so that they are not concurrently input to the up/down counter 54.

[0180] When the up count input signal is input with the initial count of "11", the count is shifted to "12". The brake signal BKS2 from the NAND gate 211 is driven high. Since the output FBS of the flip-flop 222 in the hand stopping brake signal generating means 220 remains low, the NOR gate 201 inverts the brake signal BKS2 as the brake signal BKS3 to be output. The brake circuit 23 applies a brake to the generator 20 in the governing brake control (S23 and S24). With the count staying on "12" or higher (first set value), the brake is continuously applied.

[0181] When the down count input signal is input, causing the count to become "11" or lower (S23) but not a second set value ("0") (S25), the brake signal BKS2 of the NAND gate 211 is driven low, releasing the generator 20 out of braking (brake off) (S26).

[0182] In such a brake control, the generator 20 reaches a set rotational speed, and the up count input signal and the down count input signal are alternately input to the up/down counter 54, causing the count to alternate between "12" and "11" in a locked state as shown in FIG. 18. In response to the count, the brake on and brake off are alternately repeated.

[0183] The mainspring la is unwound, outputting a smaller torque, and the brake on time is gradually shortened. The rotational speed of the generator 20 becomes close to the reference speed even with no brake applied.

[0184] With no brake applied at all, the down count input signal is more frequently input, and the up/down counter 54 gradually drops. When the count becomes the second set value "0" (S25), the output FBS of the flip-flop 222 is driven high, activating the hand stopping brake control and thereby applying a brake on the generator 20 (S27).

[0185] Once the hand stopping brake control is entered, the brake control is not released even if the up count input signal is input causing the up/down counter 54 to be "1" or higher. The generator 20 stays in the brake on state.

[0186] The hands are thus motionless or moving very slowly. Looking at the hand on the watch for the time, the user is definitely alerted to the slow-turning or motionless hand. The user operates the external operation-

al member such as the crown to close the switch 232 (S28) ; or the low-speed rotation detector 231 finds the rotational speed of the generator 20 lower than the predetermined set value (S29); or the initializing circuit 91 outputs the system reset signal SR (S30); and then a signal is input to the CLR input of the flip-flop 222 for resetting, driving the output FBS low, and thereby releasing the generator 20 out of braking (S31).

[0187] The user may thus tighten the mainspring la and correct watch time to start over with the correct hand turning.

[0188] The fourth embodiment of the present invention has the following advantages.

(12) Since the rotation control means 50 includes the hand stopping brake signal generating means 220 as well as the governing brake signal generating means 210 for performing the normal governing brake control, the generator 20 is continuously braked when a drop in the torque of the mainspring la lengthens the rotation period of the generator 20 in excess of the reference period, slowing the turning of the hand 13, and thereby leading to watch error. When the watch fails to turn the hands correctly, the hands may be forced to be motionless or be moving at a slow speed. The user may be easily alerted to watch error by the hands when checking the time, and is urged to correct the electronically-controlled, mechanical timepiece.

(13) The brake releasing means 230 is provided. Once the generator 20 is braked by the hand stopping brake signal generating means 220, the braking is not released even when the up/down counter 54 rises above the second set value ("0"). This arrangement helps the user recognize a stopped hand.

[0189] The brake is released using the brake releasing means 230. Before the hand 13 is operated for time correction or the mainspring la is tightened, the brake is released, and subsequent operations are smoothly performed.

(14) Provided as the brake releasing means 230 is the switch 232 which releases the hand stopping brake control when the user operates the external operational member such as the crown. The braking is thus released only when the user recognizes a slow-turning or motionless hand and operates the external operational member. The user is thus reliably alerted to the slow-turning or motionless hand.

(15) The crown as the external operation member permits an easier brake releasing operation than a separate dedicated button. Specifically, the user, alerted to the slow-turning hand, tightens the mainspring la winding the crown. The crown, if also designed to release the hand stopping brake, eliminates the need for the separate dedicated button for releasing the braking. This arrangement assures the ease of operation of the watch.

[0190] The generator 20, coupled to the hand 13, is continuously braked until the brake releasing. After the hand 13 is adjusted with the crown pulled, the adjustment would be canceled when the hand 13 is pushed back in, if the turning of the hand 13 fails to start over. The brake releasing is carried out at the moment the crown is pulled, and the hand 13 is reliably set into motion when the crown is pushed in after the time adjustment. The time adjustment is thus efficiently performed, and the ease of operation of the watch is assured.

(16) The low-speed rotation detector 231 is further provided as the brake releasing means 230. The hand stopping brake is automatically released without user intervention when the generator 20 rotates at a rotation period longer than the predetermined set value or at a rotation period longer than the predetermined set value for a predetermined duration of time. The user, alerted to the slow-turning hand, adjusts the hand 13 for the correct time, and the time adjustment is smoothly performed with the braking already released. The ease of operation of the watch is thus improved further.

(17) As the brake releasing means 230, the system reset signal SR from the initializing circuit 91 performs brake releasing. When the watch is left unused for a long period of time, the power supply 22 stops power feeding to the rotation control means 50, causing the rotation control means 50 to be inoperative. When the mainspring la is then tightened again to start over with clocking, the generator 20 is reliably released out of the braking. The initial operation of clocking is then smoothly performed.

(18) The up count input signal based on the rotation signal FG1 and the down count input signal based on the reference signal fs are input to the up/down counter 54. When the up/down counter 54 outputs the first set value ("12" or higher), the generator 20 is continuously braked by the brake circuit 23. When the up/down counter 54 is lower than the first set value ("11" or lower), the generator 20 is released out of the braking. The generator 20 quickly approaches the reference speed even when the rotational speed of the generator 20 deviates greatly from the reference speed at the startup. Fast rotation control response thus results.

(19) The governing brake control is set depending on whether the count is the first set value ("12" or higher) or not ("11" or lower). The hand stopping brake control is set depending on whether the count becomes the second set value ("0"). This arrangement makes it unnecessary to set separately a brake timing. Simplified construction rotation control means 50 works, reducing component cost and manufacturing cost, and thereby resulting in a low-

cost electronically-controlled, mechanical timepiece.

(20) Since the timing of the input of the up count input signal varies depending on the rotational speed of the generator 20, the duration of the first set value, namely, the brake application time is automatically adjusted. Fast and reliable response control is thus performed particularly in the locked state in which the up count input signal and the down count input signal are alternately input.

[0191] The brake signal BKS3 for the governing is input at the timing the up count input signal FG2 is input to the up/down counter 54. When the rotation period is quick or short, the brake application count per unit time is increased. When the rotation period is slow or long, the brake application count is decreased. This permits an appropriate brake control to be performed in accordance with the varying rotation period.

(21) The rotation control means 50 includes the brake circuit 23 having the transistor 23A that shorts the generator 20 for braking. The brake control means 200 feeds the brake signal of a rectangular pulse to the transistor 23A to turn it on and off, thereby controlling the generator 20 for braking. The brake circuit 23 has thus a simple construction, serving cost reduction purposes.

(22) The 4-bit up/down counter 54 counts up to 16. When the up count input signal is repeatedly input, the inputs are cumulatively counted. Within a set range, namely, a range over which the count rises up "15" or falls down to "0" with the up count input signal or the down count input signal successively input, a cumulative error is corrected. Even if the rotational speed of the generator 20 substantially deviates from the reference speed, the generator 20 reverts back to the reference speed with the cumulative error reliably corrected, though it takes time for the up/down counter 54 to reach the locked state. In the long run, this control proves effective in maintaining an accurate hand turning.

(23) The use of the up/down counter 54 permits the count, by which the hand stopping brake control is performed, to be set to a value ("0") greatly spaced apart from the count "11" close to the reference period. For this reason, even if the count drops due to a transient factor such as an impact exerted on the watch, the hand stopping brake control is not entered. The hand stopping brake control is performed only when the rotation period of the generator 20 becomes long compared with the reference period.

(24) When the up/down counter 54 outputs the count of "12" or higher (first set value), namely, within a range of 4 counts from "12" to "15", the brake is applied. When the up/down counter 54 outputs the count of "11" or lower, namely, within a range of 11 counts from "1" to "11", no brake is applied. In other words, the range of brake application is set to be narrower than the range of brake release in the count range of the up/down counter 54. The cumulative correction range, where the rotor rotation period is longer than the reference period, is thus widened, permitting reliably the correction of the cumulative error that is likely to take place with no brake applied. The rotational speed of the generator 20 is thus allowed to revert back to the reference speed.

[0192] Specifically, when the count is "12" or higher, a large torque of the mainspring 1a reduces the possibility that transient factors such as mechanical variations give rise to the input of an up count input signal. With the brake applied, it is unlikely that 3 or 4 pulses of the up count input signal are consecutively input. The generator 20 is reliably controlled even if the range of brake application is set to be as narrow as a 4-count range. On the other hand, when no brake is applied, the torque of the mainspring la is typically lowered. A transient factor, such as mechanical variations and an impact exerted on the watch, may cause the down count input signal to be input consecutively a plural number of times.

[0193] In the fourth embodiment, a 12-count range is set for the range of brake release. Even when the down count input signal is input consecutively a plural number of times, the cumulative value is stored and used to correct reliably the cumulative error.

[0194] A fifth embodiment of the present invention is now discussed referring to FIGS. 22-27. Referring to FIG. 22, the generator 20 is provided with a brake circuit 120 having a rectifier 105. Specifically, the brake circuit 120 includes switches 121 and 122 for shorting output terminals MG1 and MG2 of the generator 20 for braking. In the fourth embodiment, the switches 121 and 122 are P-channel transistors.

[0195] The voltage doubler rectifier 105 is constructed of a capacitor 123 connected to the generator 20, diodes 124, 125, and transistors 126 and 127 of switching element.

[0196] As in the preceding embodiments, the brake circuit 120 is controlled by the rotation control means 50 which is operated from power supplied by the power supply (capacitor) 22.

[0197] The rotation control means 50 includes a rotation detector 53, an up/down counter 54, a synchronizing circuit 70 and a chopper signal generator 80 as well.

[0198] The rotation detector 53 includes a waveform shaper 61 connected to the generator 20 and a monostable multivibrator 62. The waveform shaper 61 includes an amplifier and a comparator, and converts a sinusoidal wave signal into a rectangular wave signal. The monostable multivibrator 62 works as a bandpass filter that passes pulses having a period longer than a certain value, and outputs a rotation signal FG1 with noise filtered out therefrom.

[0199] The rotation signal FG1 from the rotation de-

tector 53 and the reference signal fs from the frequency divider 52 are respectively input to an up count input and a down count input of an up/down counter 54 via the synchronizing circuit 70.

[0200] The up/down counter 54 remains unchanged from that used in the fourth embodiment, and is a 4-bit counter with its initial count set to "11".

[0201] The up/down counter 54 has 4 bit outputs QA-QD. As shown in FIG. 23, when the count is a first set value ("12" or higher), both the third and fourth bit outputs QC and QD give a high-level signal. When the count is "11" or lower, at least one of the third and fourth bit outputs QC and QD gives a low-level signal.

[0202] The output LBS1 of an AND gate 110, to which outputs QC and QD are input, gives a high-level signal when the up/down counter 54 outputs the count of "12" or higher, and gives a low-level signal when the up/down counter 54 outputs the count of "11" or lower.

[0203] The outputs QA-QD are input to an NAND gate 111 and an OR gate 112. The outputs of the NAND gate 111 and OR gate 112 are respectively fed to NAND gates 102, to which the outputs of the synchronizing circuit 70 are respectively input. Now suppose that the up count input signal is fed a plural number of times causing the count to rise to "15" and a low-level signal to be output from the NAND gate 111. Then, if a further up count input signal is input to the NAND gate 102, the input is canceled, and no further up count input signal afterward is input to the up/down counter 54. In the same manner as in the first embodiment, the count is prevented from shifting "15" to "0", or shifting from "0" to "15".

[0204] Outputs QB, QC and QD of the up/down counter 54 are also input to the OR gate 113, and the output FBS2 of the OR gate 113 is input to a second counter 115. Referring to FIG. 25, the second counter 115 is designed to start counting a 1-Hz clock from the frequency divider 52 when the up/down counter 54 gives the count of "0" or "1", driving the output FBS2 low in level. Output LBS2 from a third bit output Q3 of the second counter 115 alternates between a high-level signal and a low-level signal every four clocks, namely, every four seconds for the 1-Hz clock.

[0205] The output LBS1 of the AND gate 110 and the output LBS2 of the second counter 115 are input to an OR gate 116. The output of the OR gate 116 is input to the chopper signal generator 80.

[0206] Since the up/down counter 54 gives the count of "0" or "1", the output LBS1 of the AND gate 110 is a low-level signal, and the output LBS2 is directly input to the chopper signal generator 80.

[0207] When the up/down counter 54 gives the count of "2" or higher, the output FBS2 of the OR gate 113 becomes a high-level signal, disabling the second counter 115 and thereby causing the LBS2 to remain low. The output LBS1 of the AND gate 110 is directly input to the chopper signal generator 80.

[0208] The chopper signal generator 80 includes first chopper signal generating means 81, constructed of three AND gates 82-84, for outputting a first chopper signal CHI based on the outputs Q5-Q8 of the frequency divider 52, second chopper signal generating means 85, constructed of two OR gates 86 and 87, for outputting a second chopper signal CH2 based on the outputs Q5-Q8 of the frequency divider 52, an AND gate 88 for receiving the output of the OR gate 116 and the output CH2 of the second chopper signal generating means 85, and a NOR gate 89 for receiving the output of the AND gate 88 and the output CH1 of the first chopper signal generating means 81.

[0209] The output CH3 of the NOR gate 89 in the chopper signal generator 80 is input to the gates of switches 121 and 122 constructed of P-channel transistors. When the CH3 is a low-level signal, the switches 121 and 122 are kept turned on, shorting the generator 20 for braking.

[0210] When the CH3 is a high-level signal, the switches 121 and 122 are kept turned off, applying no brake on the generator 20. The chopper signal from the output CH3 thus controls the generator 20 in choppering control.

[0211] The operation of the fifth embodiment is discussed referring to timing diagrams shown in FIGS. 23-25, an output waveform diagram shown in FIG. 26, and a flow diagram shown in FIG. 27.

[0212] When the generator 20 starts operating, causing the initializing circuit 91 to output a low-level system reset signal SR to the load input of the up/down counter 54 (S41), the up count input signal based on the rotation signal FG1 and the down count input signal based on the reference signal fs are input to the up/down counter 54 as shown in FIG. 23. These signals are adjusted through the synchronizing circuit 70 so that they are not concurrently input to the up/down counter 54.

[0213] When the up count input signal is input to the up/down counter 54 with the initial count of "11", the count is shifted to "12". The LBS1 is driven high, and is directly input to the AND gate 88 in the chopper signal generator 80.

[0214] When the down count input signal is input, causing the count back to "11", the output LBS1 is driven low and is directly input to the AND gate 88 in the chopper signal generator 80.

[0215] Referring to FIG. 24, in the chopper signal generator 80, the first chopper signal generating means 81 gives the output CH1 and the second chopper signal generating means 85 gives the output CH2, based on the outputs Q5-Q8 of the frequency divider 52.

[0216] When the count becomes the first set value ("12"-"15") (S43), the output of the AND gate 88 is driven high. The output CH3 of the NOR gate 89 is a chopper signal, which is an inverted CH2, having a duty factor of a long low-level duration (brake on time) and a short high-level duration (brake off time). The brake on time of the reference period becomes long, and the governing brake control (brake on control) is performed to the generator 20. The brake is turned off at regular intervals

in chopper control. A drop in generated power is controlled while braking torque is increased (S44).

[0217] When the count is "11" or lower (S43) but "2" or higher (S45), the output of the AND gate 88 is a low-level signal. The output CH3 of the NOR gate 89 is a chopper signal, which is an inverted CH1, having a duty factor (the ratio of turn on of the switch 121 to that of the switch 122) of a long high-level signal (brake on time) and a short low-level signal (brake off time). The brake on time of the reference period becomes short, and practically, no brake is applied to the generator 20. Specifically, the brake off control with a priority placed on power generation is performed (S46).

[0218] In the fifth embodiment, during the low-level LBS signal, the duty factor of the CH3 chopper signal (high-level duration:low-level duration) is 15:1, namely, 1/16=0.0625. During the high-level LBS signal, the duty factor of the CH3 chopper signal is 1:15 (high-level duration:low-level duration), namely, 15/16=0.9375.

[0219] Referring to FIG. 26, the generator 20 outputs, across MG1 and MG2, an alternating current in accordance with the change in magnetic flux. Depending on the output LBS1 and LBS2 signals, the chopper signals CH3 at a constant frequency but different duty factors are appropriately fed to the switches 121 and 122. When the high-level LBS1 and LBS2 signals are output, namely, during the brake on control, the braking time in each chopper cycle is lengthened. The amount of braking increases, reducing the rotational speed of the generator 20. As the brake is applied, generated power is reduced, accordingly. However, energy accumulated during the braking is output when the chopper signal turns off the switches 121 and 122, and is used to step up the output voltage of the generator 20. In this way, a reduction in generated power during the braking is compensated for. The braking torque is thus increased while the reduction in generated power is restricted.

[0220] When the low-level LBS1 and LBS2 signals are output, namely, during the brake off control, the braking time in the chopper cycle is shortened, increasing the rotational speed of the generator 20. In this case, also, the chopper signal turns the switches 121 and 122 from on to off, chopper voltage stepup results. The generated power is large compared with the generated power under the control under which no brake is applied at all.

[0221] The alternating current output of the generator 20 is stepped up and rectified through the voltage doubler rectifier 105, and charges the power supply (capacitor) 22, which in turn drives the rotation control means 50.

[0222] The mainspring 1a is unwound, outputting a smaller torque, and the brake on time is gradually shortened. The rotational speed of the generator 20 becomes close to the reference speed even with no brake applied.

[0223] When the count drops down to the second set value ("1" or "0") (S45), the hand stopping brake control is performed (S47). During the hand stopping brake control, the second counter 115 gives the output LBS2 that alternates between high level and low level every 4 seconds, and inputs it to the AND gate 88 in the chopper signal generator 80, and the brake on control and brake off control are alternately performed to the generator 20. Since the brake on control of 4 seconds is long enough relative to the rotation period of the generator 20, a resulting brake is sufficiently strong to the generator 20, causing the hand to stop. When the count is the second set value, the mainspring 1a presents a small torque, and even if the braking is released for every 4 seconds, the hand 13 is unlikely to move. The hand turning firmly stays motionless, at least, for 4-second brake on control periods consecutively for several times. In this way, the user is alerted to the slow-turning or motionless hand, and is urged to tighten the mainspring 1a.

[0224] Upon noticing the slow-turning hand, the user tightens the mainspring 1a, and the mainspring 1a transmits torque to the generator 20. When the brake on control is performed on the generator 20, the generator 20 does not turn even if torque is applied thereon. During the hand stopping brake control in this embodiment, however, at least each 4-second brake release time is permitted. During this time, the generator 20 may be driven. When the up count input signal is fed with the generator 20 moving, the up/down counter 54 shifts from the second set value (to "2" or higher), the hand stopping brake control is released and the watch reverts back to its normal operating condition.

[0225] The fifth embodiment presents the advantages (12), (18)-(24), which are also provided by the fourth embodiment. The fifth embodiment further presents the following advantages.

(25) When the up/down counter 54 reaches the second set value ("0" or "1"), the brake on and brake off in the predetermined period are repeated based on the output LBS2 of the second counter 115. The hand stopping brake control automatically offers the duration of the brake releasing. If the user tightens the mainspring la upon noticing the slow-turning hand, the generator 20 operates during the brake release duration in the hand stopping brake control. The up/down counter 54 then rises to "2" or higher, releasing the hand stopping brake control and putting the watch back to the normal operating condition. The fifth embodiment does not require the brake releasing means 230, which is needed in the first embodiment, and eliminates the need for the separate brake release operation. This arrangement not only assures the ease of operation but also reduces the cost of the watch.

(26) Since two types of chopper signals CH3 having different duty factors are used to perform the brake on control and the brake off control, the magnitude of braking (braking torque) is increased without lowering the charging voltage (generated voltage). Since the chopper signal having a large duty factor

is used for controlling, particularly during the brake on duration, the braking torque is increased while controlling a drop in the charging voltage. In this way, the reliability of the watch is maintained while an efficient brake control is attained at the same time. A long operation time is thus permitted in the electronically-controlled, mechanical timepiece.

(27) Since the chopper signal having a small duty factor is used for the chopper control during the brake off control period, the charging voltage is increased during the brake off duration.

(28) The change in the output level of the output QD, namely, the switch timing between the brake on control and the brake off control, is synchronized with the transition of the chopper signal CH3 from on to off. Impulses having a high voltage component are regularly output in synchronization with the chopper signal CH3 of the generator 20. This output may be used as a watch error measurement pulse.

[0226] When the output LBS and the chopper signal CH3 are not synchronized with each other, the generator 20 generates high voltage component at the change in the output LBS, independently from the constant period chopper signal CH3. For this reason, the "impulses" in the waveform of the output voltage from the generator 20 do not necessarily have a constant period, and are not appropriate for use as the watch error measurement pulse. However, if the synchronization is assured as in this embodiment, the impulses serve as the watch error measurement pulse.

(29) The fifth embodiment makes use of the two types of control: the governing brake control and the hand stopping brake control. These controls achieve different brake application times by using the outputs of the up/down counter 54 and the second counter 115, and commonly use the remaining blocks including the synchronizing circuit 70, chopper signal generator 80, and brake circuit 120. The component count and the cost of the watch are thus reduced.

[0227] A sixth embodiment of the present invention is now discussed referring to FIG. 28. Rather than using the first and second set values in the up/down counter 54, the sixth embodiment performs both the governing brake control and the hand stopping brake control by a single set value.

[0228] Specifically, in the sixth embodiment, as in the first and fourth embodiments, the brake circuit 23 having a transistor 23B as a switching element connects to the generator 20, and the output QD of the up/down counter 54 controls the brake circuit 23 to govern the generator 20.

[0229] The up/down counter 54 receives, at its up count input and down count input via the synchronizing circuit 70, respectively, the rotation signal FG1 of the rotation detector 53 constructed of the waveform shaper 61 and the monostable multivibrator 62 and the reference signal fs from the frequency divider 52 as the reference signal generating means.

[0230] The up/down counter 54 is a 4-bit counter. The up/down counter 54 is provided with four data input terminals preset terminals) A through D. Terminals A through C are pulled up to a high level, setting the initial value preset value) of the up/down counter 54 at "7".

[0231] A startup and initializing circuit 90 is connected to the load input of the up/down counter 54. The startup and initializing circuit 90 includes an initializing circuit 91, connected to the capacitor 22, for outputting a system reset signal SR when power is initially fed to the capacitor 22, a frequency divider 92, reset by the system reset signal RS, for counting the predetermined number of pulses of rotation signal FG1, a flip-flop 93, reset by the system reset signal SR; for receiving the clock signal from the frequency divider 92.

[0232] The frequency divider 92, formed of 4 stages of flip-flops, outputs a high-level signal when it receives 16 pulses of the rotation signal FG1. When receiving 16 pulses of the rotation signal FG1 from the input of the system reset signal SR, the flip-flop 93 outputs a high-level signal to the load input of the up/down counter 54.

[0233] Since the up/down counter 54 does not accept the up and down inputs for a constant duration of time from the input of the system reset signal SR to the transition of the load input to a high level, the up/down counter 54 is maintained at the count of "7".

[0234] The up/down counter 54 is provided with 4-bit outputs QA-QD. The fourth bit output QD outputs a low-level signal when the count is 7 or lower, and outputs a high-level signal when the count is 8 or higher. The output QD is connected to the gate of the N-channel transistor 23B in the brake circuit 23 connected in parallel with the generator 20. When the count comes to within a range of "8"-"15", the output QD gives a high-level signal to the gate of the transistor 23B. The transistor 23B is turned on, shorting the generator 20 and thereby applying a brake on it.

[0235] When the count falls within a range of "0" to "7", the output QD outputs a low-level signal, which lowers the gate voltage of the transistor 23B. The transistor 23B is turned off, keeping the generator 20 from being braked. Since the brake circuit 23 is controlled by the output QD of the up/down counter 54, the up/down counter 54 also serves as the brake control means 200. Counts "8" through "15", out of the counts output by the up/down counter 54, serve as the first and second set values.

[0236] Unlike the preceding embodiments, the up/down counter 54 is not associated with the NAND gate 102 which prevents the count from shifting from the minimum value "0" to the maximum "15", or from the maximum value "15" to the minimum value "0". For this reason, the up/down counter shifts to the maximum count "15" when a down count input signal is further applied

to the up/down counter when the up/down counter gives the minimum count "0", and shifts to the minimum count "0" when an up count input signal is further applied to the up/down counter when the up/down counter gives the maximum count "15".

[0237] In the sixth embodiment, as in the first embodiment, the count goes to "8" in response to the up count input signal that is input with the count at "7", and the output QD becomes a high-level signal. The generator 20 is braked in the governing brake control. As long as the count comes to within a range of "8"-"15" (first set value), the generator 20 is continuously braked.

[0238] When the down count input signal is input causing the count to "7" or lower (first set value), the output QD becomes a low-level signal. The generator 20 is released out of braking.

[0239] The mainspring la is unwound, outputting a smaller torque, and the brake on time is gradually shortened as shown in FIG. 8. The rotational speed of the generator 20 becomes close to the reference speed even with no brake applied.

[0240] Even with no brake applied at all, the down count input signal is more frequently input and the count gradually drops. When the count drops to "0", and then shifts to "15", the output QD becomes a high-level signal, putting the generator 20 in a brake control state. The brake is continuously applied as long as the count falls within a range of "8" through "15". When the mainspring 1a outputs a small torque, the hand remains motionless. The count within a range of "8" through "15" serves as the first set value for the governing brake control and the second set value for the hand stopping brake control, and the two controls are performed within the same count range. However, which control to perform, the governing brake control or the hand stopping brake control, is automatically determined by the magnitude of the torque of the mainspring 1a.

[0241] When the brake control is performed with a small torque by the mainspring la, the hand is motionless or is moving at a very slow speed. Looking at the hand 13 for checking the time, the user easily notices the slow-turning or motionless hand.

[0242] Upon noticing the slow-turning or motionless hand, the user tightens the mainspring la, which in turn transmits torque to the generator 20. If the generator 20 is continuously in the brake on control state, the generator 20 remains unable to function even under torque. In the sixth embodiment, with the rotation signal FG1 not input, the 8-Hz reference signal fs only is input gradually changing the count, and within about 1 second, the brake off state is reached (the count within a range of "7"-"0"). In the meantime, the generator 20 is allowed to function. When the generator 20 operates causing the initializing circuit 91 to output the system reset signal SR, the initial state is recovered. With the time adjustment performed, the normal clocking state resumes.

[0243] The sixth embodiment presents the advantages (12), (18)-(23), which are also provided by the fourth embodiment. The sixth embodiment further presents the following advantages.

(30) The up/down counter 54 is capable of changing its count between "0" and "15". The brake control is performed not only when an up count input signal is input to the up/down counter 54 with its initial count set "7", causing thereafter the count to rise to the first set value (within a range of "8" through "15"), but also when a down count input signal is input to the up/down counter 54 with its initial count set to "7". causing the count to drop to "0" and then shift to the second set value, namely, the first set value ("15"-"8"). The up/down counter 54 thus serves as both the governing brake signal generating means 210 and the hand stopping brake signal generating means 220. The component count and the cost of the watch are thus reduced.

(31) When the up/down counter 54 gives a count other than the first (second) set value, the brake is automatically released. In the hand stopped state, the brake release is repeated at regular intervals, and the brake releasing means 230 used in the first embodiment is dispensed with. This arrangement eliminates the need for the separate brake release operation, and assures the ease of operation while reducing the cost of the watch.

[0244] The present invention is not limited to the above embodiments, and is intended to cover various modifications and equivalent arrangements included within the scope of the appended claims.

[0245] The up/down counter 54 employs a 4-bit up/down counter, but 3-bit or smaller up/down counter or 5-bit or larger up/down counter may be employed. A larger bit-number counter increases the range of count, presenting an increased range for storing a cumulative error. This is particularly useful in the control in the unlocked state immediately subsequent to the startup of the generator 20. With a smaller bit-number counter, the range for storing the cumulative error is narrow, but since the count up and count down are repeated in the locked state, a 1-bit counter works, contributing to the cost reduction of the watch.

[0246] The particular count "8" or "12" serves as a threshold. Alternatively, the brake may be applied anywhere within a range of "11" through "15". Preferably, the range of brake application is narrower than the range of brake release. However, depending on the setting on the watch, the range of brake application may be set to be equal to the range of brake release. The range of brake release (brake off) may be set to be wider than the range of brake application.

[0247] The range of brake application preferably includes the maximum or minimum count (for example, "15" or "0"). With the maximum or minimum count included therein, the brake control signals may be easily formed using the outputs QA-QD of the up/down counter

54. The construction of the brake control means is thus simplified.

[0248] The counting means is not limited to the up/down counter. The first and second counting means ar separately arranged for the reference signal fs and the rotation signal FG1. In such a case, the comparing means (comparator) for comparing the counts from the counting means needs to be separately arranged. The use of the up/down counter 54 advantageously presents a simpler construction.

[0249] The use of the startup and initializing circuit 90 is not a requirement, but is preferable in that a priority is placed on power generation at the startup of the generator 20, permitting the rotation control means 50 to be fast driven. The construction of the startup and initializing circuit 90 is not limited to the one shown in connection with the preceding embodiments.

[0250] As in the third and fifth embodiments, the first, second, fourth and sixth embodiments may perform chopper control in which the chopper pulse is added to the brake signals applied to the transistors 23A and 23B. The chopper control permits the increase in brake torque while keeping generated power above a constant level.

[0251] The constructions of the brake circuit 23, brake control means 200, synchronizing circuit 70 and the like are not limited to the ones described in connection the preceding embodiments. Any appropriate construction for these units may be employed.

[0252] The brake releasing means is not limited the one in the preceding embodiments. A brake releasing button may be arranged as the external operational member. Pressing this button releases the brake.

[0253] In the fifth embodiment, the brake on and brake off are alternated every 4 seconds in the hand stopping brake control. The braking time for applying a brake may be determined considering the mechanical load of the watch and the torque of the mainspring, and is typically 2 to 6 seconds.

[0254] In the fourth and fifth embodiments, the first set value is within the range of "12" through "15" in the up/down counter 54. In the sixth embodiment, the first and second set values are within the range of "8" through "15". The first set value (including the case where the first set value is equal to the second set value) may be appropriately determined depending on the type of watch to be controlled and the number of bits of the up/down counter 54. As in the preceding embodiments, if the range of brake application includes the maximum or minimum count (for example, "15" or "0"), the brake control signals may be easily formed using the outputs QA-QD of the up/down counter 54. The construction of the brake control means is thus simplified.

[0255] In the fourth and fifth embodiments, the second set value, different from the first set value, is not limited to "0" and "1".

[0256] The construction of the up/down counter 54 is not limited to the one already described. It is important that the counter 54 count the up count input signal and down count input signal and determine the difference between both counts.

[0257] The first through third embodiments may include the governing brake signal generating means 210, hand stopping brake signal generating means 220 and brake releasing means 230, used in the fourth through sixth embodiments.

[Advantages]

[0258] According to the first aspect of the present invention, the electronically-controlled, mechanical timepiece and the control method for the watch feature fast response governing control and low-cost design.

[0259] According to the second aspect of the present invention, the electronically-controlled, mechanical timepiece and the control method for the watch alert the user to a slow time and helps the user avoid using the watch without noticing it.

Claims

1. An electronically-controlled, mechanical timepiece comprising a mechanical energy source, a generator, connected to said mechanical energy source via a train wheel and driven by said mechanical energy source, for generating induced power to feed electric energy, a hand connected to said train wheel, rotation control means, driven by said electric energy, for controlling the rotation period of said generator,

   wherein said rotation control means comprises rotation detecting means for detecting the rotation period of said generator and for outputting a rotation signal corresponding to said rotation period, reference signal generating means for generating a reference signal based on a signal from a time reference source, first counting means for counting the reference signal from said reference signal generating means, second counting means for counting said rotation signal from said rotation detecting means, and brake control means which controls said generator so that said generator is braked when a first count provided by said first counting means is smaller than a second count provided by said second counting means and is not braked when said first count is equal to or greater than said second count.

2. An electronically-controlled, mechanical timepiece according to Claim 1, wherein said brake control means further comprises comparing means for comparing the count provided by said first counting means with the count provided by said second

counting means.

3. An electronically-controlled, mechanical timepiece according to Claim 2, wherein said first counting means, said second counting means and said comparing means are formed of an up/down counter.

4. An electronically-controlled, mechanical timepiece according to Claim 3, wherein said up/down counter counts and holds at least three values.

5. An electronically-controlled, mechanical timepiece according to one of Claims 1 through 4, wherein said rotation control means, when initially supplied with electric energy by said generator, keeps said brake control means in an inoperative state until the number of revolutions of said generator reaches a predetermined value.

6. An electronically-controlled, mechanical timepiece according to one of Claims 3 and 4, wherein a particular threshold is set in said up/down counter so that the braking of said generator is initiated or released when the count of said up/down counter crosses the threshold.

7. An electronically-controlled, mechanical timepiece according to Claim 6, wherein said up/down counter is set within a range of ± 1 of said threshold when said generator initially feeds electric energy to said up/down counter.

8. An electronically-controlled, mechanical timepiece according to Claim 4, wherein said up/down counter is set such that a count range, extending over a plurality of counts, within which said generator is braked, is narrower than a count range within which said generator is not braked.

9. An electronically-controlled, mechanical timepiece comprising a mechanical energy source, a train wheel driven by said mechanical energy source, a generator, driven by mechanical energy transmitted from said mechanical energy source through said train wheel, for feeding electric energy, a hand connected to said train wheel, rotation control means, driven by said electric energy, for controlling the rotation period of said generator,

   wherein said rotation control means comprises:
   rotation detecting means for detecting the rotation period of said generator and for outputting a rotation signal corresponding to said rotation period,
   reference signal generating mean for generating a reference signal based on a signal from a time reference source,
   an up/down counter which receives one of said rotation signal and said reference signal as an up count input signal and the other of said rotation signal and said reference signal as a down count input signal, and
   brake control means which controls said generator by applying a governing brake on said generator when the rotation period of said generator gets shorter, causing the count of said up/down counter to reach a first set value, and by applying a hand stopping brake on said generator when the rotation period of said generator gets longer than a reference period with no brake applied on said generator, causing the count of said up/down counter to reach a second set value.

10. An electronically-controlled, mechanical timepiece according to Claim 9, wherein said brake control means comprises brake releasing means for releasing the hand stopping brake, and wherein the hand stopping brake, once initiated, is continuously applied until the brake is released by said brake releasing means.

11. An electronically-controlled, mechanical timepiece according to Claim 10, wherein said brake releasing means releases the hand stopping brake in response to the operation of an external operational member by a user.

12. An electronically-controlled, mechanical timepiece according to Claim 11, wherein said external operational member is a crown.

13. An electronically-controlled, mechanical timepiece according to one of Claims 10 through 12, wherein said brake releasing means comprises a low-speed rotation detector for detecting the rotational speed of said generator when the rotational speed of said generator becomes lower than a set value, and wherein said brake releasing means releases the hand stopping brake when the low-speed rotation detector circuit detects a rotational speed of said generator lower than said set value.

14. An electronically-controlled, mechanical timepiece according to one of Claims 10 through 13, wherein said brake releasing means releases the hand stopping brake when a predetermined duration of time elapses from the moment the hand stopping brake was applied.

15. An electronically-controlled, mechanical timepiece according to Claim 9, wherein said brake control means performs controlling which alternates between a predetermined duration of brake application and a predetermined duration of brake release, for a duration throughout which said up/down coun-

ter gives said second set value.

16. An electronically-controlled, mechanical timepiece according to Claim 9, wherein said second set value is equal to said first set value, and wherein the brake control for the governing brake by said brake control means and the brake control for the hand stopping brake by said brake control means are identical to each other.

17. An electronically-controlled, mechanical timepiece according to Claim 16, wherein said up/down counter shifts to the maximum count when a down count input signal is further applied to said up/down counter when said up/down counter gives the minimum count, and shifts to the minimum count when an up count input signal is further applied to said up/down counter when said up/down counter gives the maximum count.

18. A control method of an electronically-controlled, mechanical timepiece comprising a mechanical energy source, a generator, connected to said mechanical energy source via a train wheel and driven by said mechanical energy source, for generating induced power to feed electric energy, a hand connected to said train wheel, rotation control means, driven by said electric energy, for controlling the rotation period of said generator, said method comprising the steps of:

counting a reference signal based on a signal from a time reference source to determine a first count,
counting a rotation signal that is output in accordance with the rotation period of said generator to determine a second count, and
controlling said generator by applying a brake on said generator when said first count is smaller than said second count, and by not applying a brake on said generator when said first count is equal to or greater than said second count.

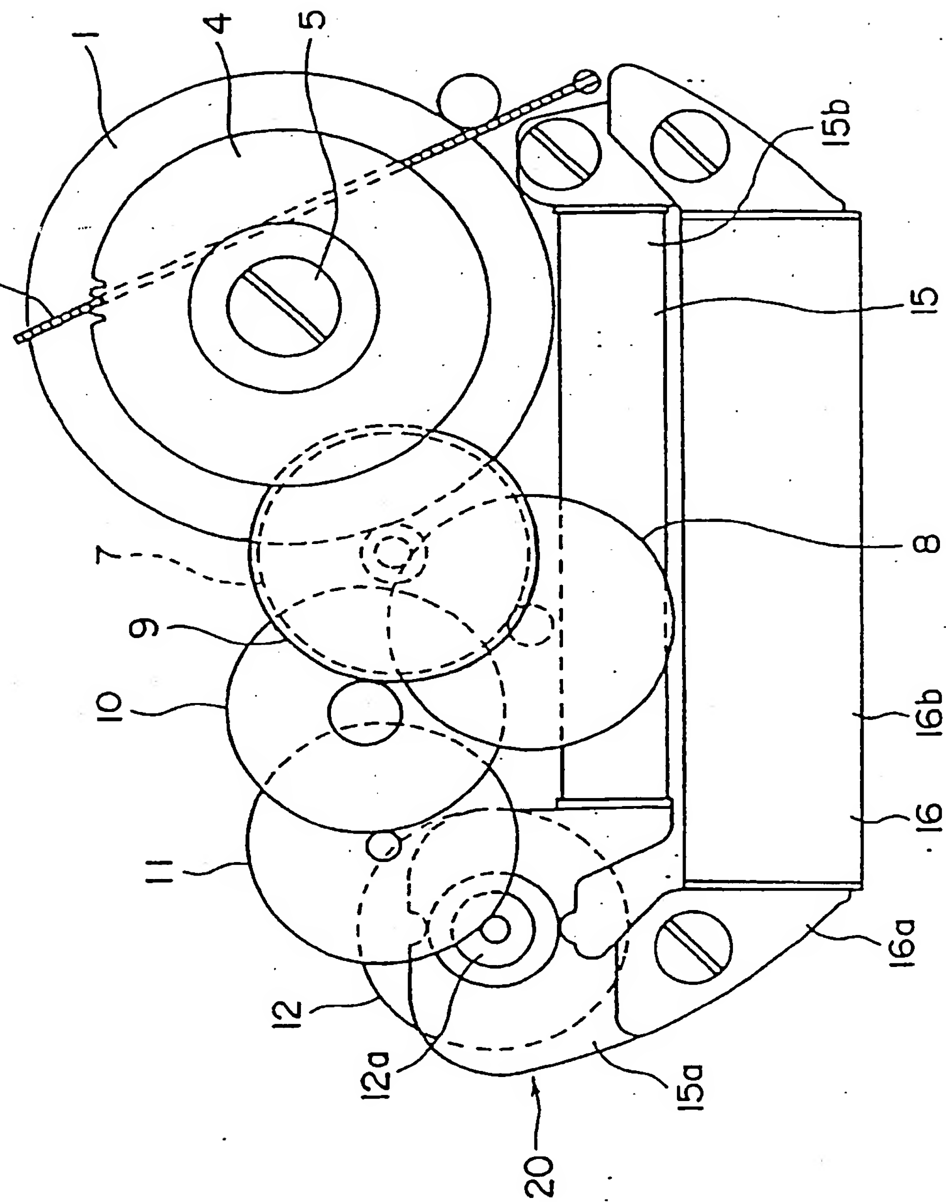
19. A control method of an electronically-controlled, mechanical timepiece comprising a mechanical energy source, a generator, connected to said mechanical energy source via a train wheel and driven by said mechanical energy source, for generating induced power to feed electric energy, a hand connected to said train wheel, rotation control means, driven by said electric energy, for controlling the rotation period of said generator, said method comprising the steps of:

inputting, to an up/down counter, a reference signal based on a signal from a time reference source and a rotation signal that is output in accordance with the rotation period of said generator, with one of said reference signal and said rotation signal as an up count input signal and the other of said reference signal and said rotation signal as a down count input signal, applying a brake on said generator when said up/down counter reaches a predetermined value, and not applying a brake on said generator when said up/down counter gives a value other than said predetermined value.

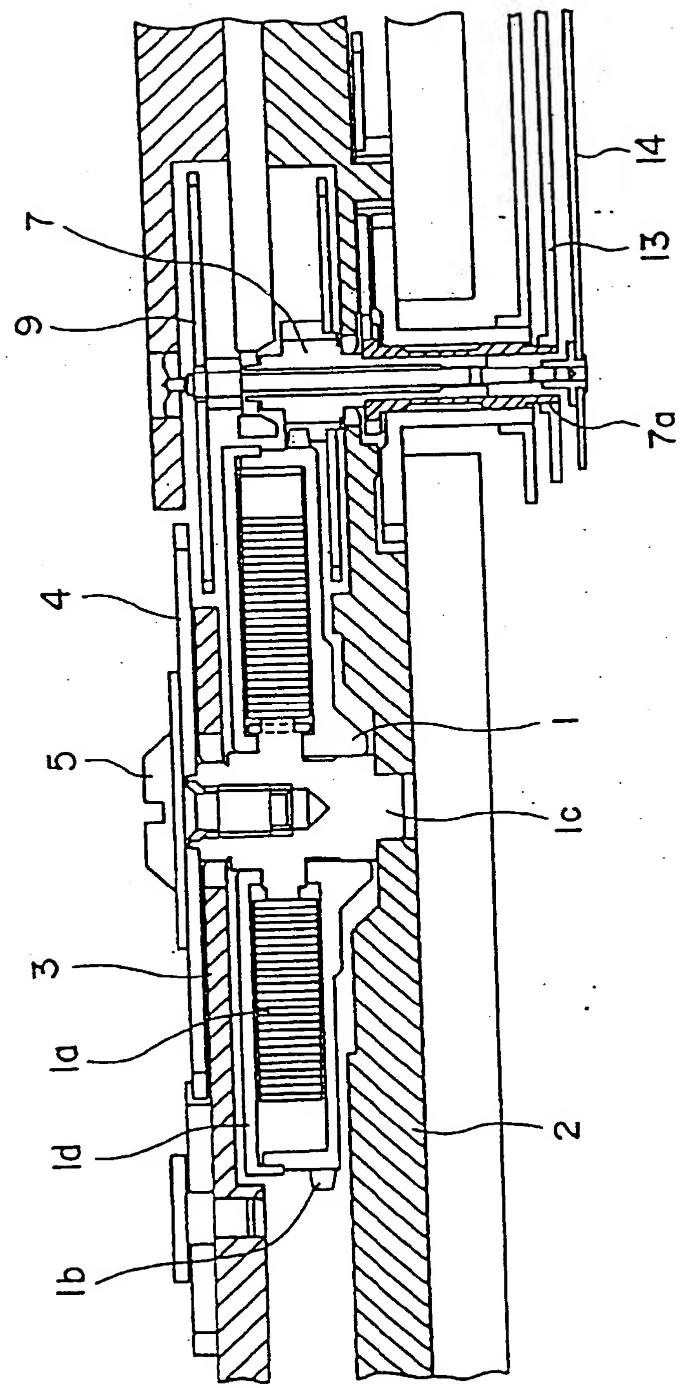
20. A control method of an electronically-controlled, mechanical timepiece comprising a mechanical energy source, a generator, connected to said mechanical energy source via a train wheel and driven by said mechanical energy source, for generating induced power to feed electric energy, a hand connected to said train wheel, rotation control means, driven by said electric energy, for controlling the rotation period of said generator, said method comprising the steps of:

inputting, to an up/down counter, a reference signal based on a signal from a time reference source and a rotation signal that is output in accordance with the rotation period of said generator, with one of said reference signal and said rotation signal as an up count input signal and the other of said reference signal and said rotation signal as a down count input signal, controlling said generator by applying a governing brake on said generator when the rotation period of said generator gets shorter, causing the count of said up/down counter to reach a first set value, and by applying a hand stopping brake on said generator when the rotation period of said generator gets longer than a reference period with no brake applied on said generator, causing the count of said up/down counter to reach a second set value.

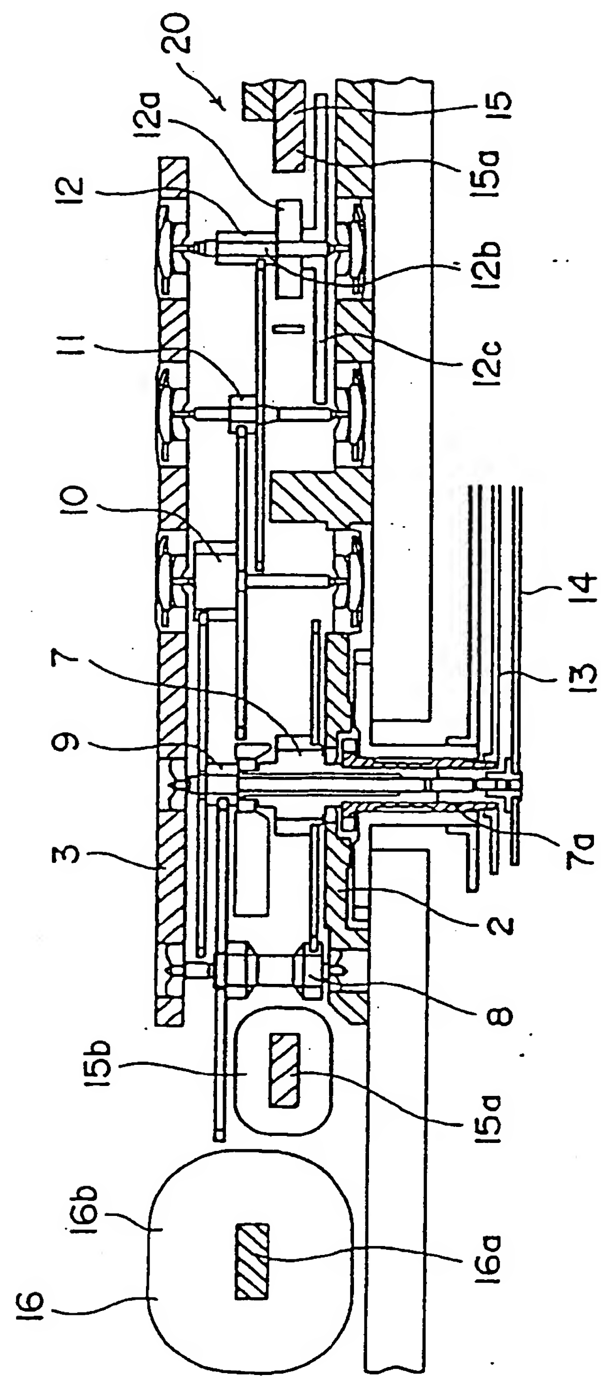
[FIG. 1]



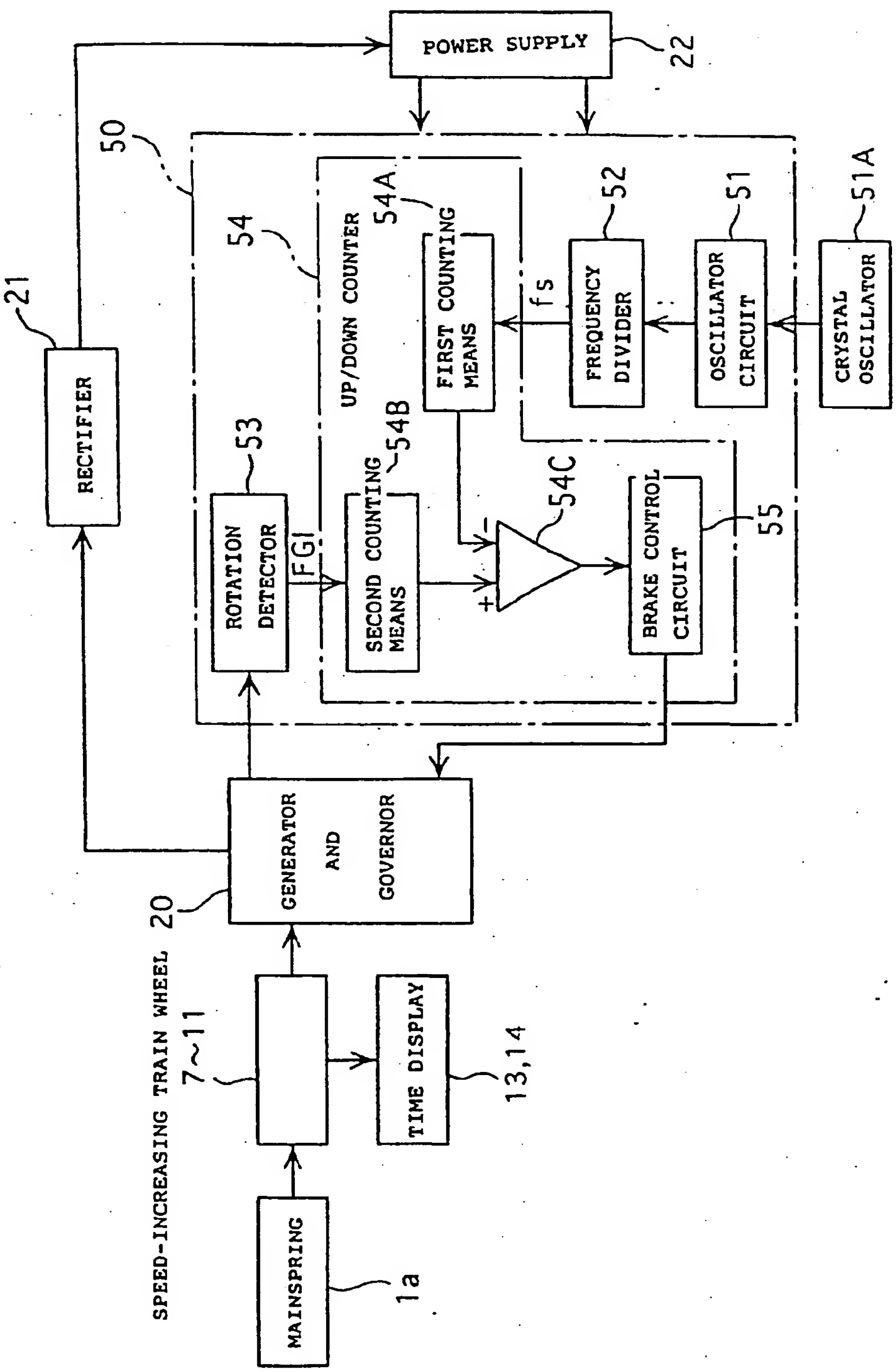
[FIG. 2]



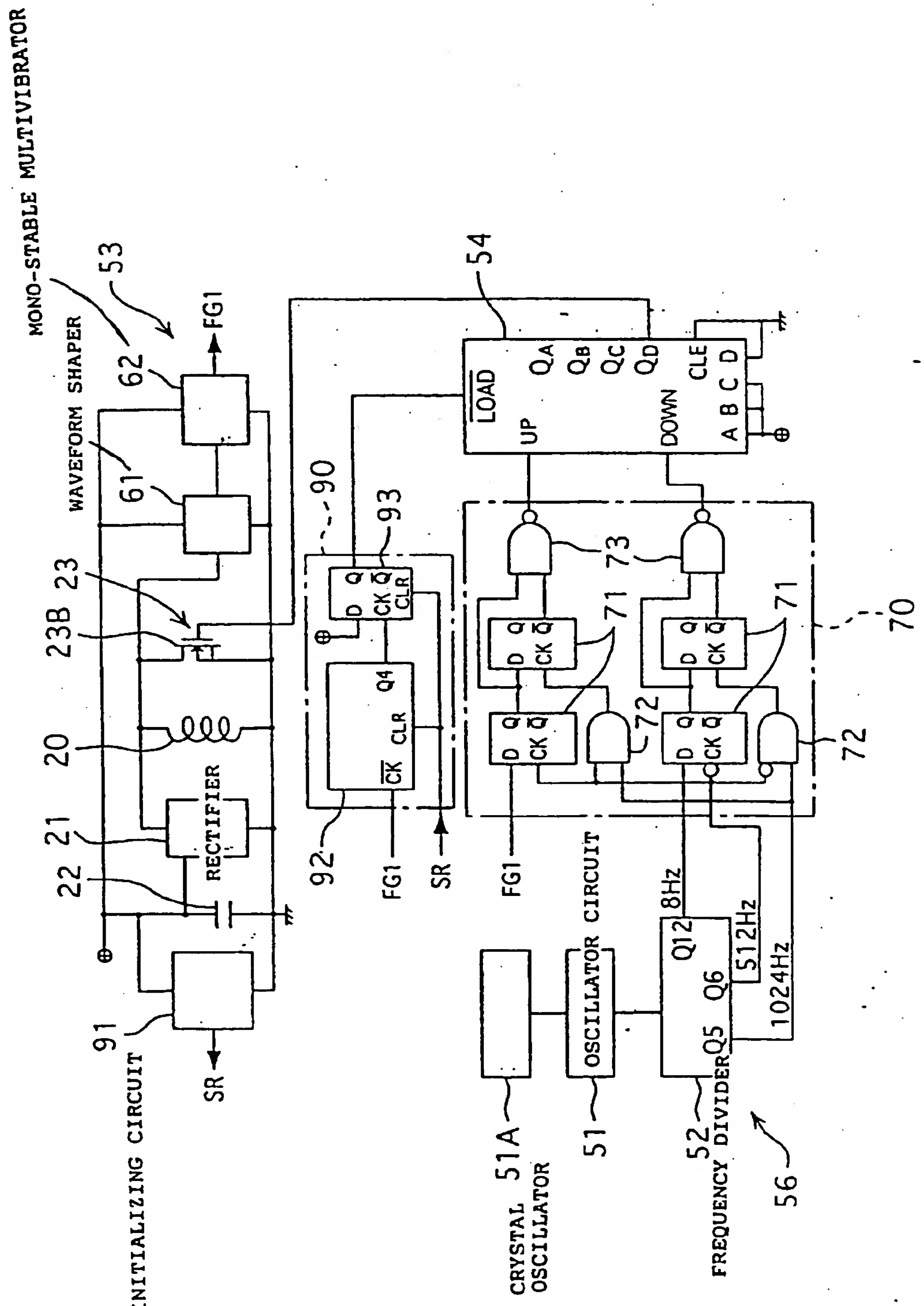
[FIG. 3]



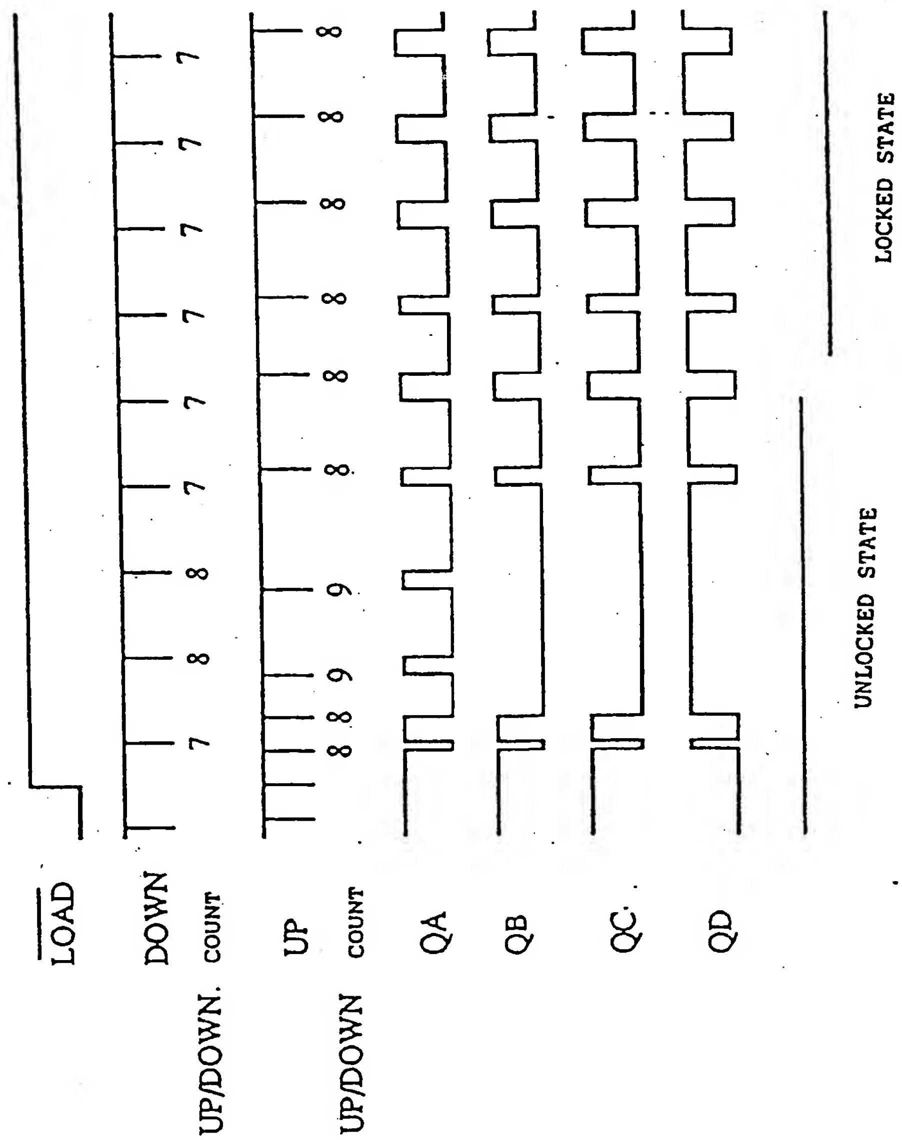
[FIG. 4]


POWER SUPPLY
22
50
RECTIFIER
21
54
UP/DOWN COUNTER
54A
FIRST COUNTING MEANS
fs
FREQUENCY DIVIDER
52
OSCILLATOR CIRCUIT
51
CRYSTAL OSCILLATOR
51A
53
ROTATION DETECTOR
FG1
SECOND COUNTING MEANS
54B
54C
BRAKE CONTROL CIRCUIT
55
GENERATOR AND GOVERNOR
20
SPEED-INCREASING TRAIN WHEEL
7~11
TIME DISPLAY
13,14
MAINSPRING
1a

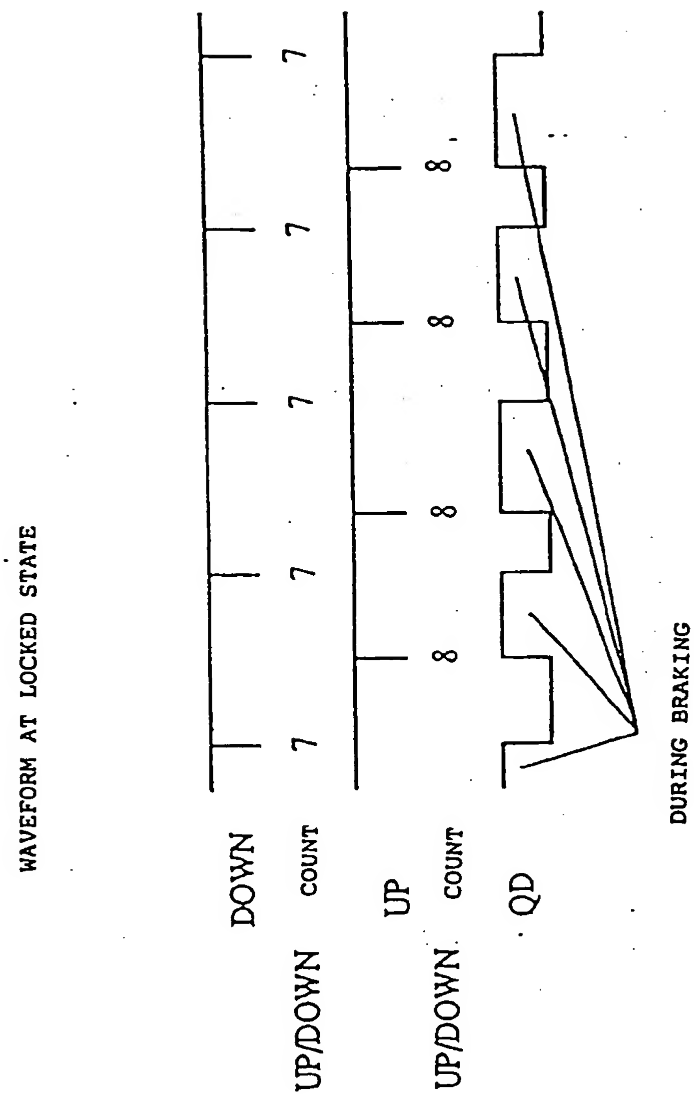
[FIG. 5]


MONO-STABLE MULTIVIBRATOR
WAVEFORM SHAPER
53
62
61
FG1
23
23B
20
21
RECTIFIER
22
91
SR
INITIALIZING CIRCUIT
90
93
92
FG1
SR
54
LOAD
UP
DOWN
CLE
A B C D
70
71
72
73
FG1
8Hz
512Hz
1024Hz
Q12
Q6
Q5
OSCILLATOR CIRCUIT
CRYSTAL OSCILLATOR
51A
51
52
FREQUENCY DIVIDER
56

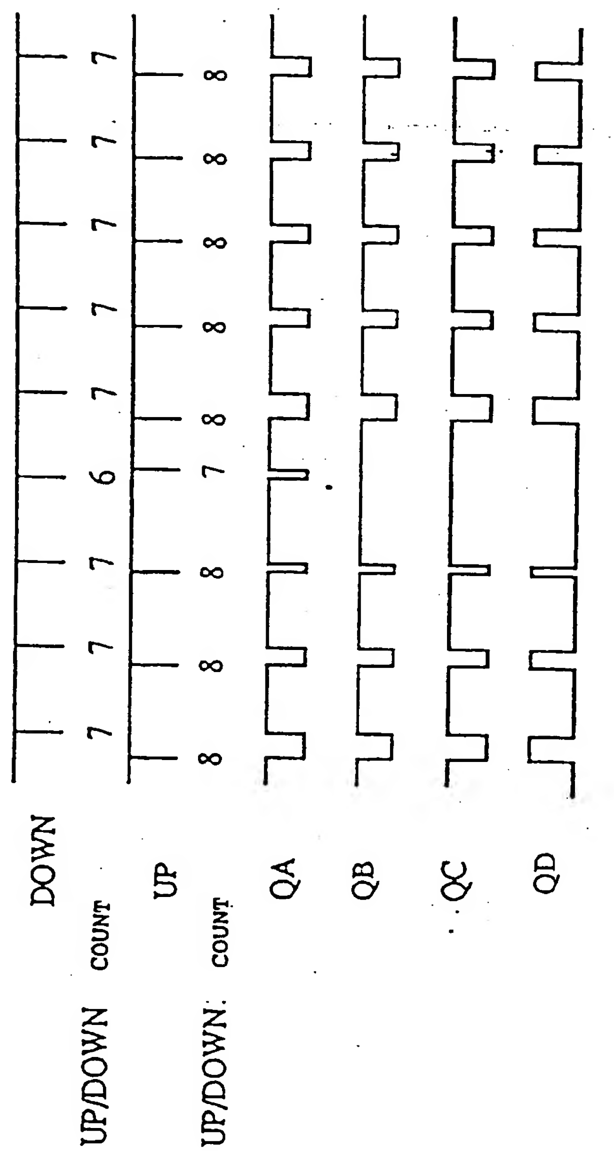
[FIG. 6]


LOAD
UP/DOWN. DOWN COUNT
UP/DOWN UP COUNT
QA
QB
QC
QD
UNLOCKED STATE
LOCKED STATE
7 8 8 7 7 7 7 7 7 7
8 8 9 9 8 8 8 8 8 8

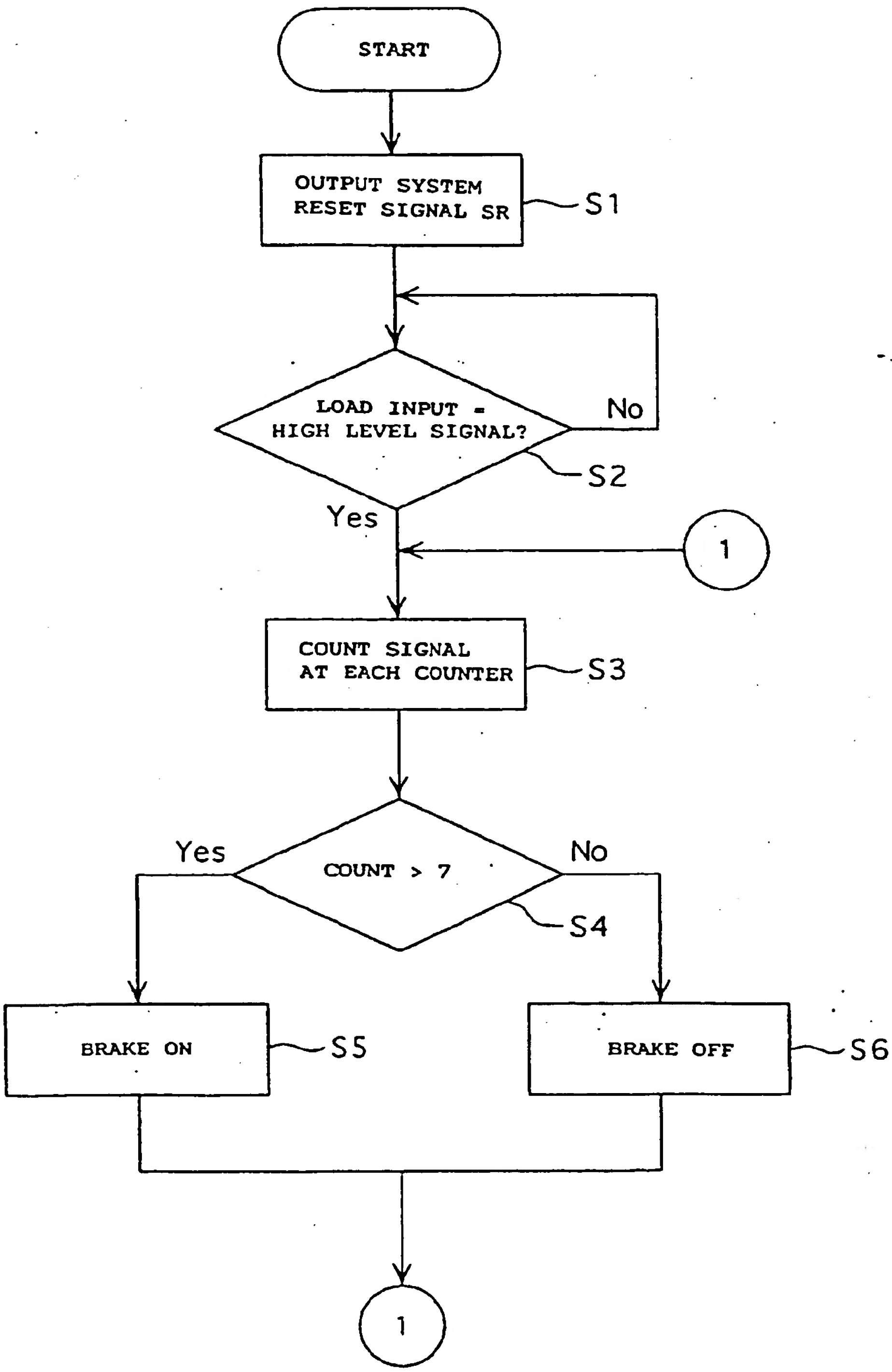
[FIG. 7]


WAVEFORM AT LOCKED STATE
DOWN
UP/DOWN COUNT
7 7 7 7 7
UP
UP/DOWN COUNT
8 8 8 8
QD
DURING BRAKING

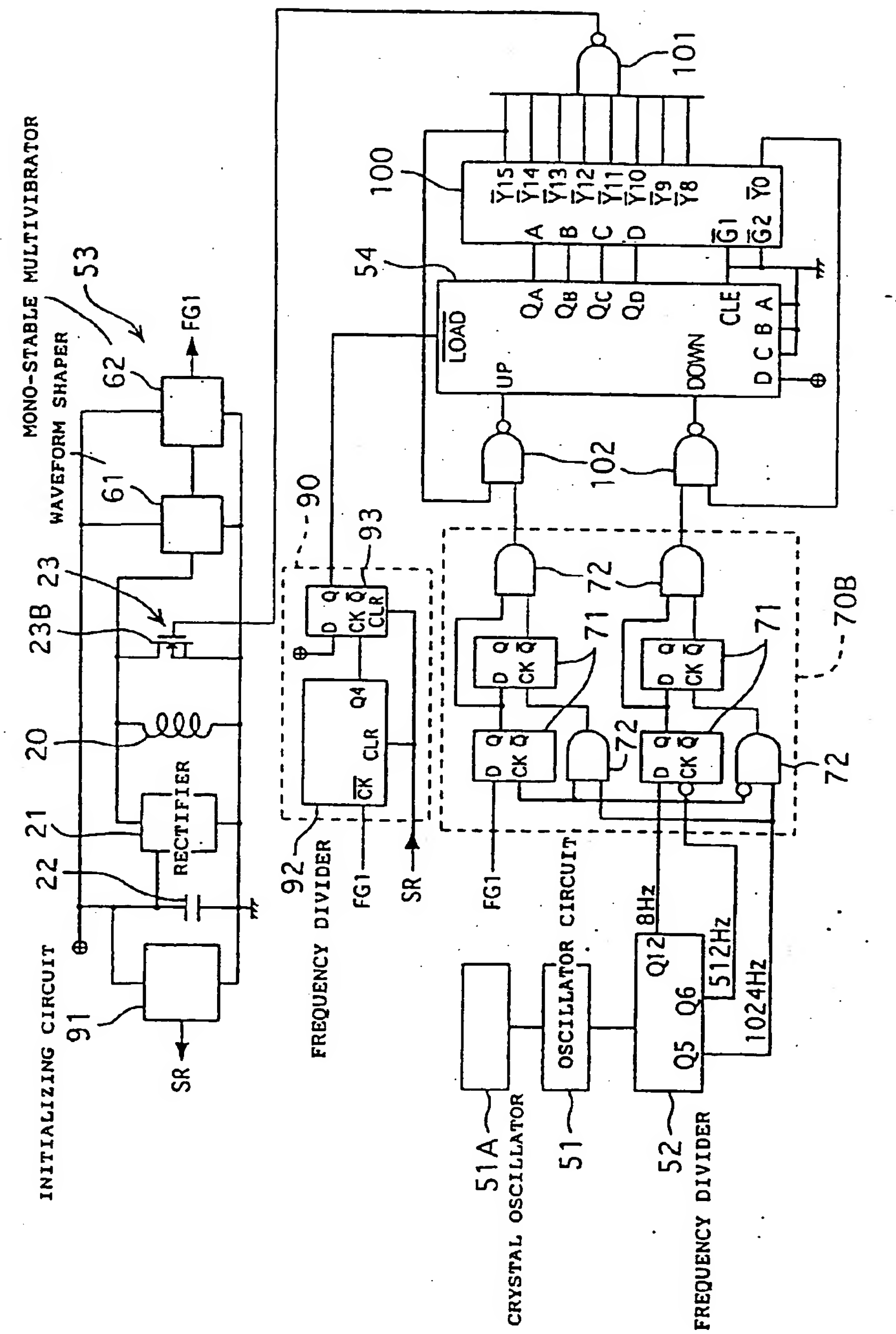
[FIG. 8]


DOWN
UP/DOWN COUNT
7 7 7 6 7 7 7 7 7
UP
UP/DOWN COUNT
8 8 8 7 8 8 8 8 8
QA
QB
QC
QD

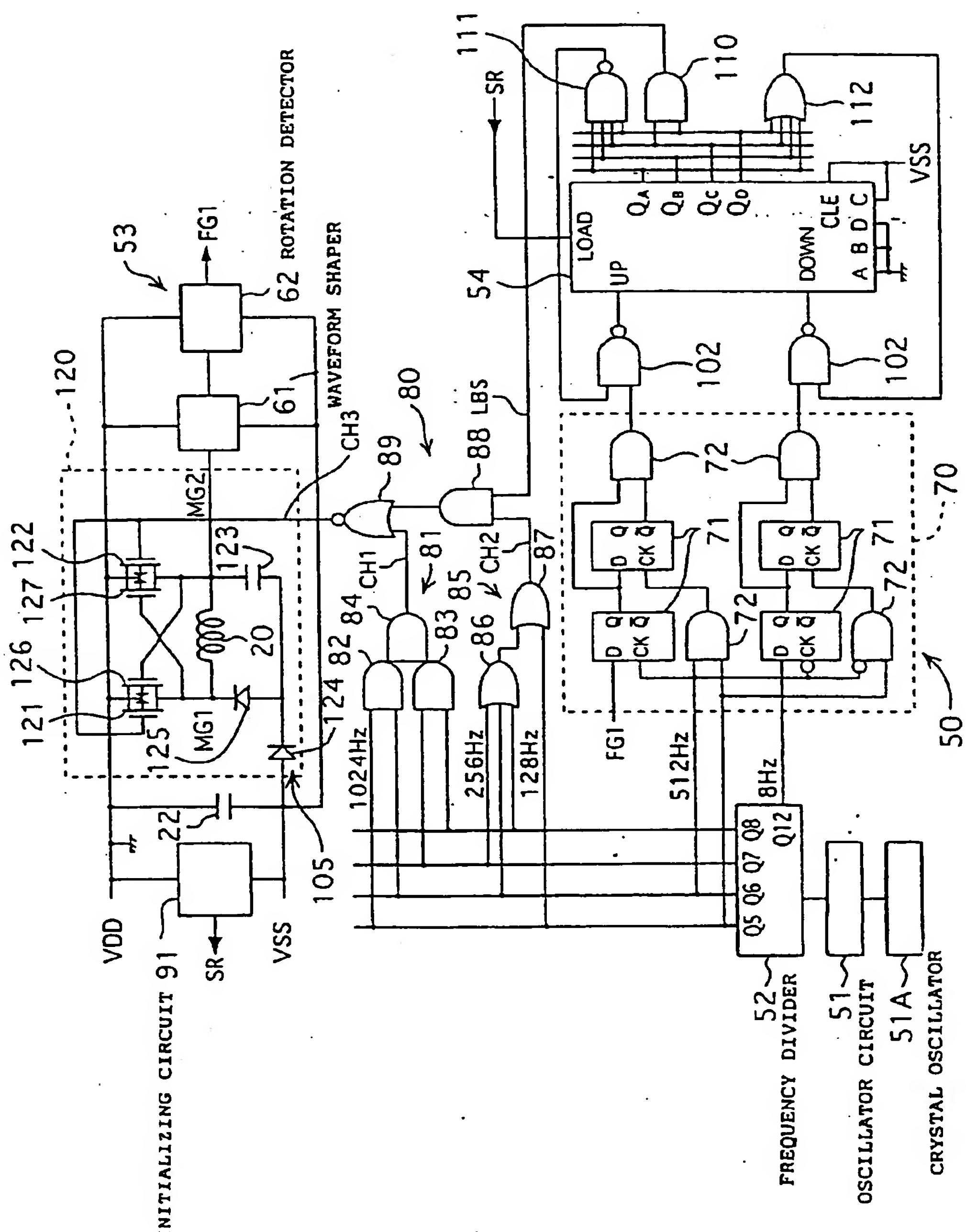
[FIG.9]


START
OUTPUT SYSTEM RESET SIGNAL SR
S1
LOAD INPUT = HIGH LEVEL SIGNAL?
No
S2
Yes
1
COUNT SIGNAL AT EACH COUNTER
S3
COUNT > 7
Yes
No
S4
BRAKE ON
S5
BRAKE OFF
S6
1

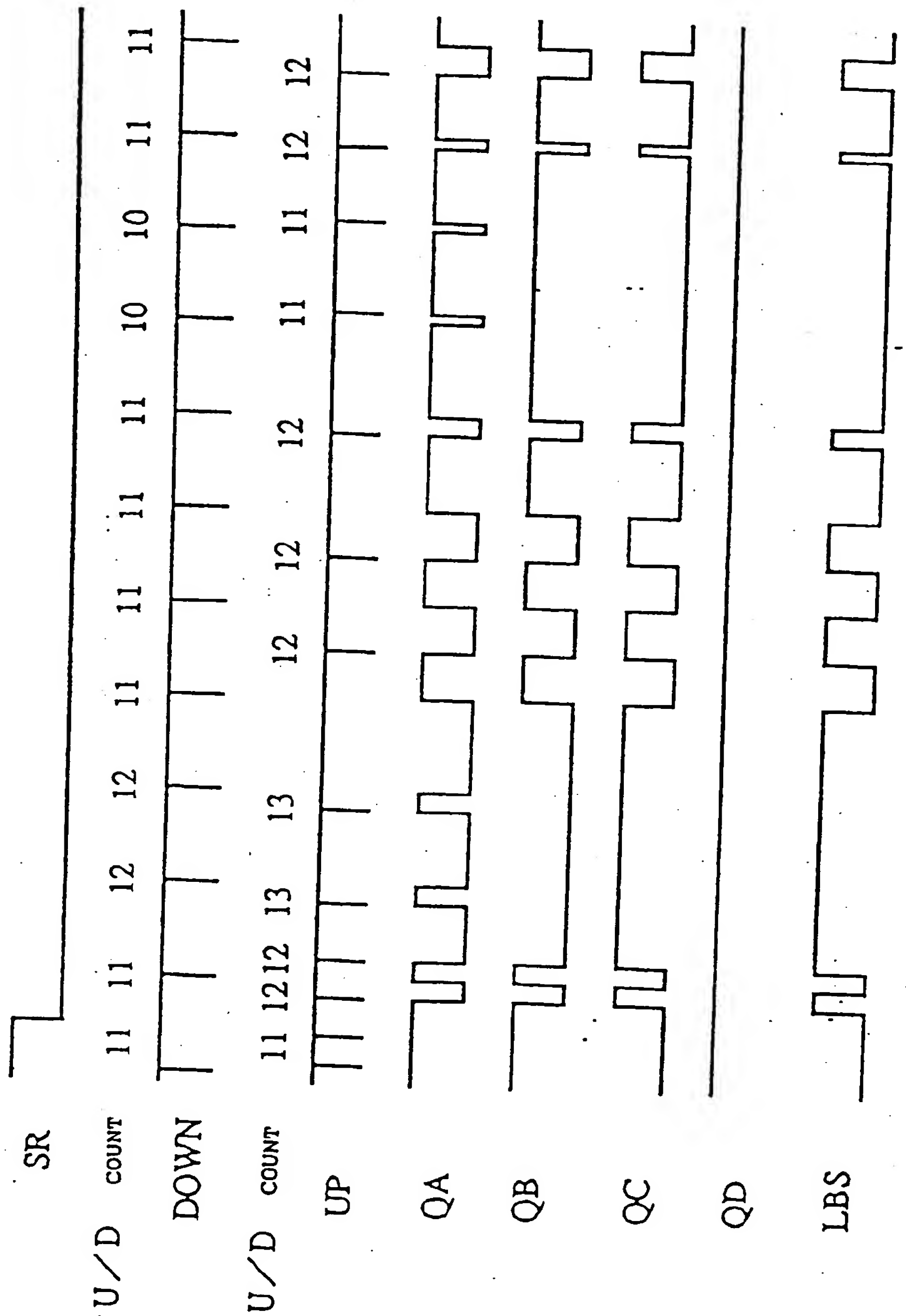
[FIG. 10]


INITIALIZING CIRCUIT
91
SR
22
21
RECTIFIER
20
23B
23
61
62
WAVEFORM SHAPER
MONO-STABLE MULTIVIBRATOR
53
FG1
90
93
92
FREQUENCY DIVIDER
FG1
SR
D Q CK Q̄ CLR
CK CLR Q4
FG1
70B
71
72
102
54
LOAD
UP
DOWN
QA QB QC QD
CLE
D C B A
100
A B C D
G1 G2
Y15 Y14 Y13 Y12 Y11 Y10 Y9 Y8 Y0
101
8Hz
512Hz
1024Hz
Q12 Q6 Q5
51A
CRYSTAL OSCILLATOR
51
OSCILLATOR CIRCUIT
52
FREQUENCY DIVIDER

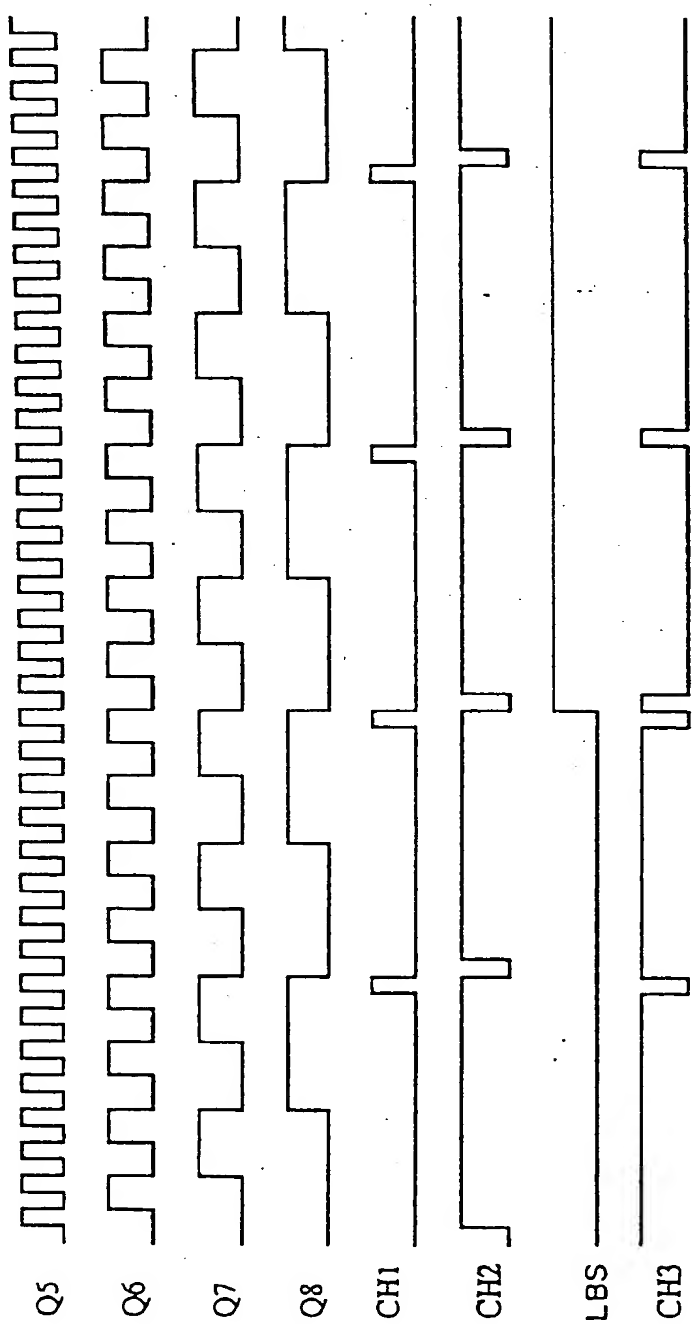
[FIG. 11]


INITIALIZING CIRCUIT 91
ROTATION DETECTOR
WAVEFORM SHAPER
FREQUENCY DIVIDER
OSCILLATOR CIRCUIT
CRYSTAL OSCILLATOR
VDD
VSS
SR
FG1
1024Hz
256Hz
128Hz
512Hz
8Hz
LBS
LOAD
UP
DOWN
CLE

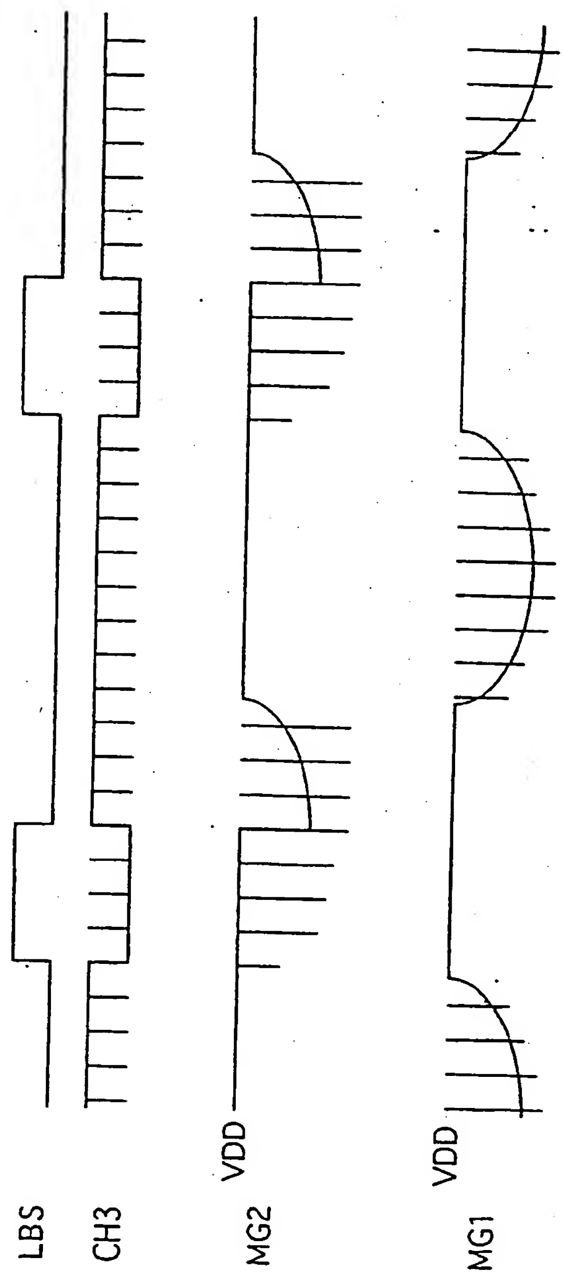
[FIG. 12]


SR
U/D COUNT
11 11 12 12 12 11 11 11 11 11 10 10 11 11
DOWN
U/D COUNT
11 12 12 12 13 13 12 12 12 12 11 11 12 12
UP
QA
QB
QC
QD
LBS

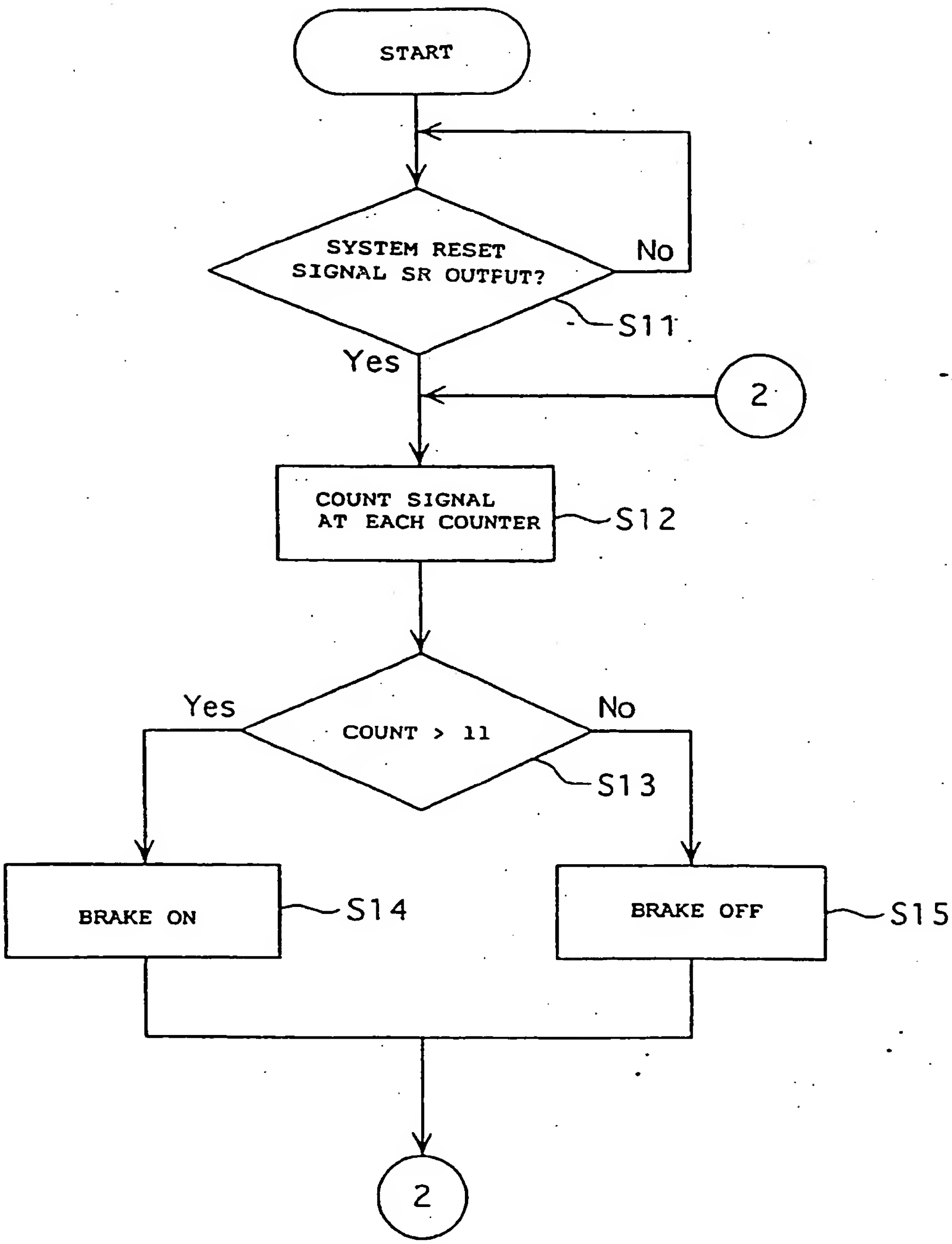
[FIG. 13]



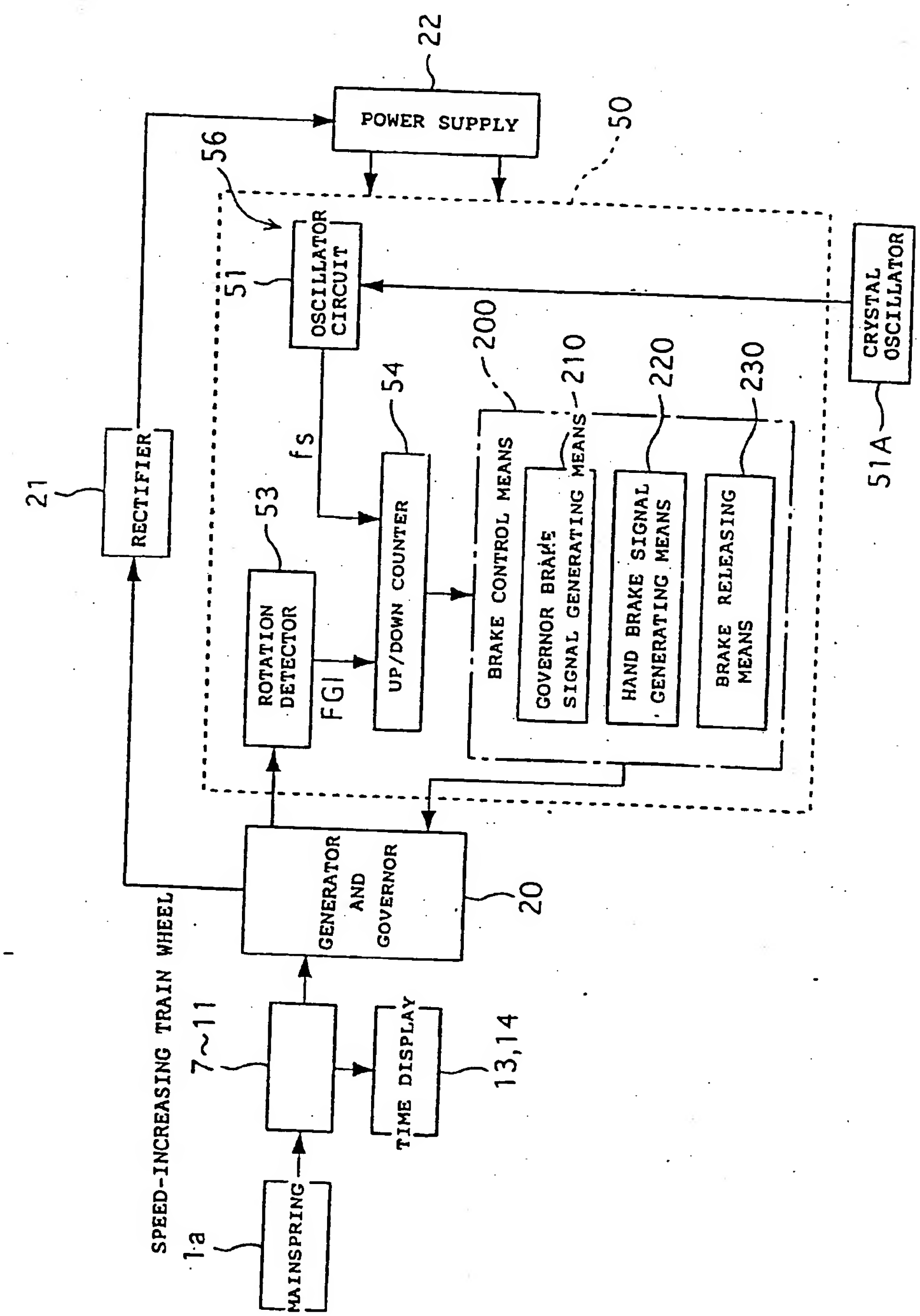
[FIG. 14]



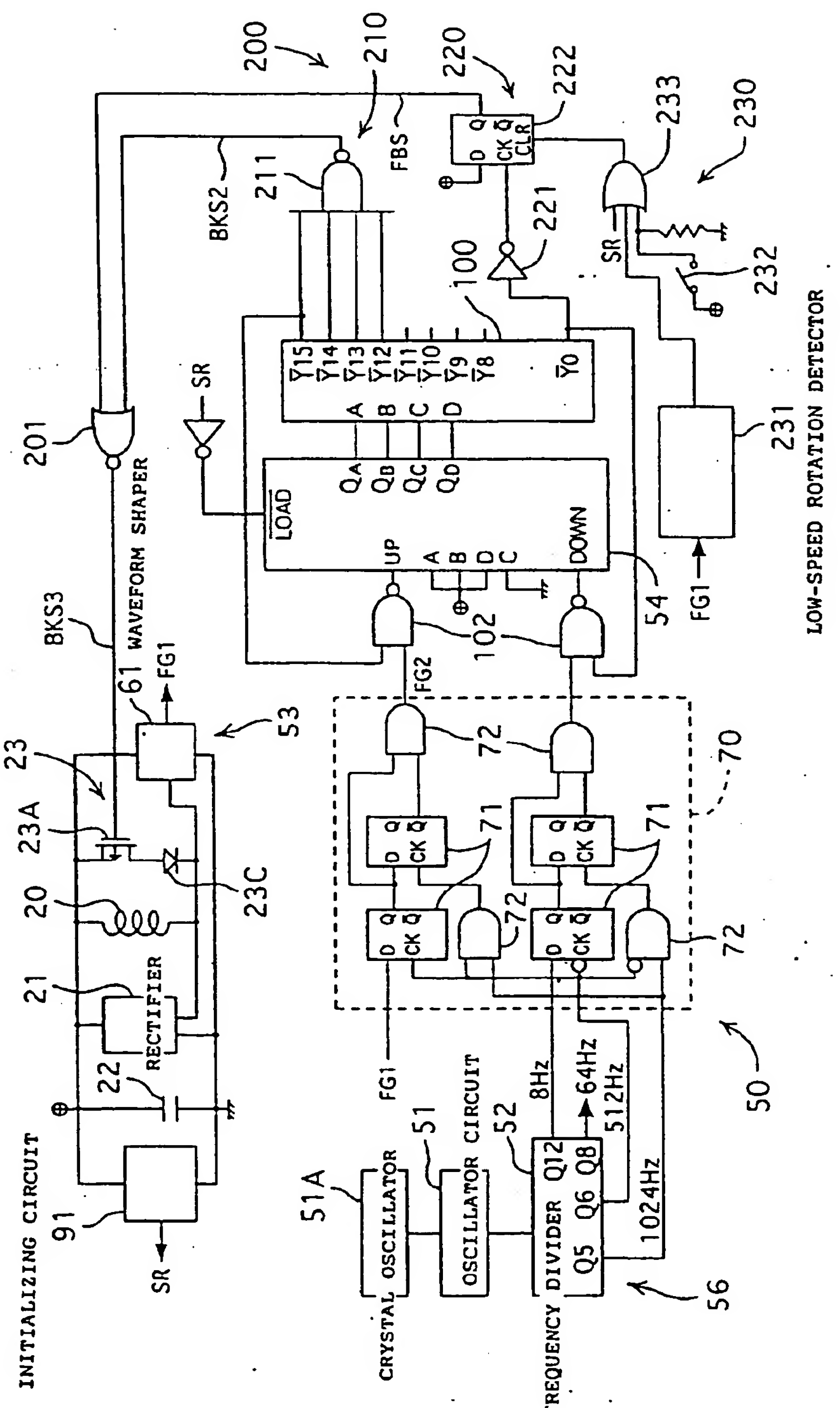
[FIG. 15]


START
SYSTEM RESET SIGNAL SR OUTPUT?
No
S11
Yes
2
COUNT SIGNAL AT EACH COUNTER
S12
Yes
COUNT > 11
No
S13
BRAKE ON
S14
BRAKE OFF
S15
2

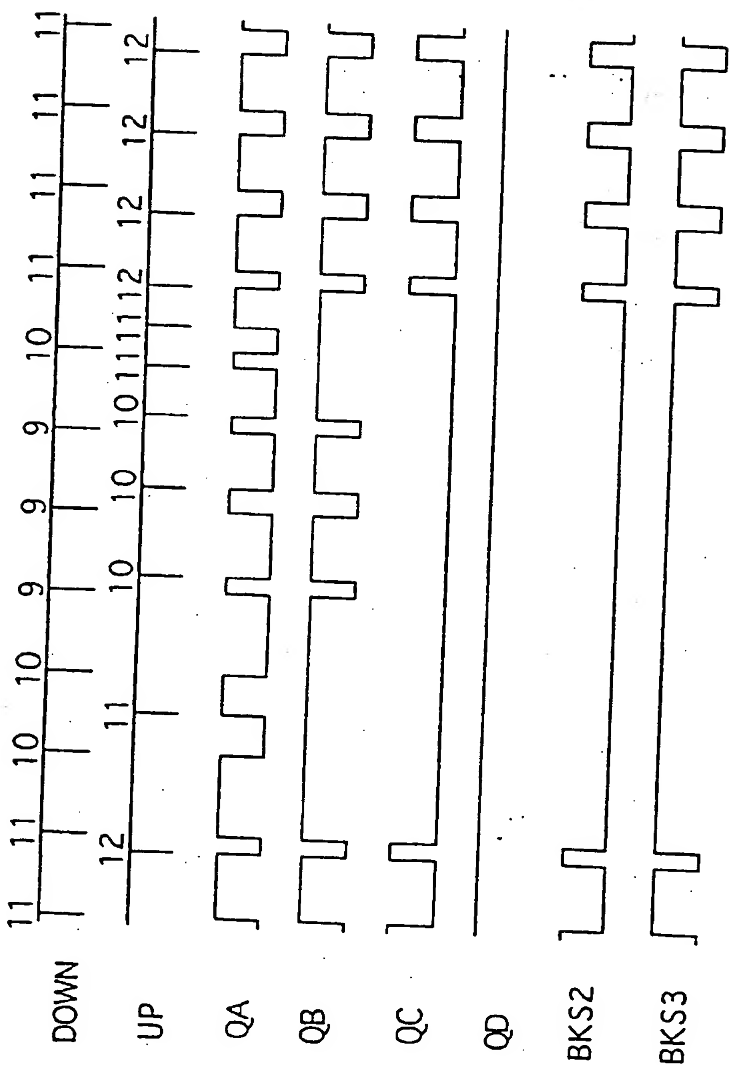
[FIG. 16]


POWER SUPPLY
22
50
56
OSCILLATOR CIRCUIT
51
CRYSTAL OSCILLATOR
51A
200
BRAKE CONTROL MEANS
210
GOVERNOR BRAKE SIGNAL GENERATING MEANS
220
HAND BRAKE SIGNAL GENERATING MEANS
230
BRAKE RELEASING MEANS
54
UP/DOWN COUNTER
fs
53
ROTATION DETECTOR
FG1
21
RECTIFIER
GENERATOR AND GOVERNOR
20
SPEED-INCREASING TRAIN WHEEL
7~11
TIME DISPLAY
13,14
MAINSPRING
1a

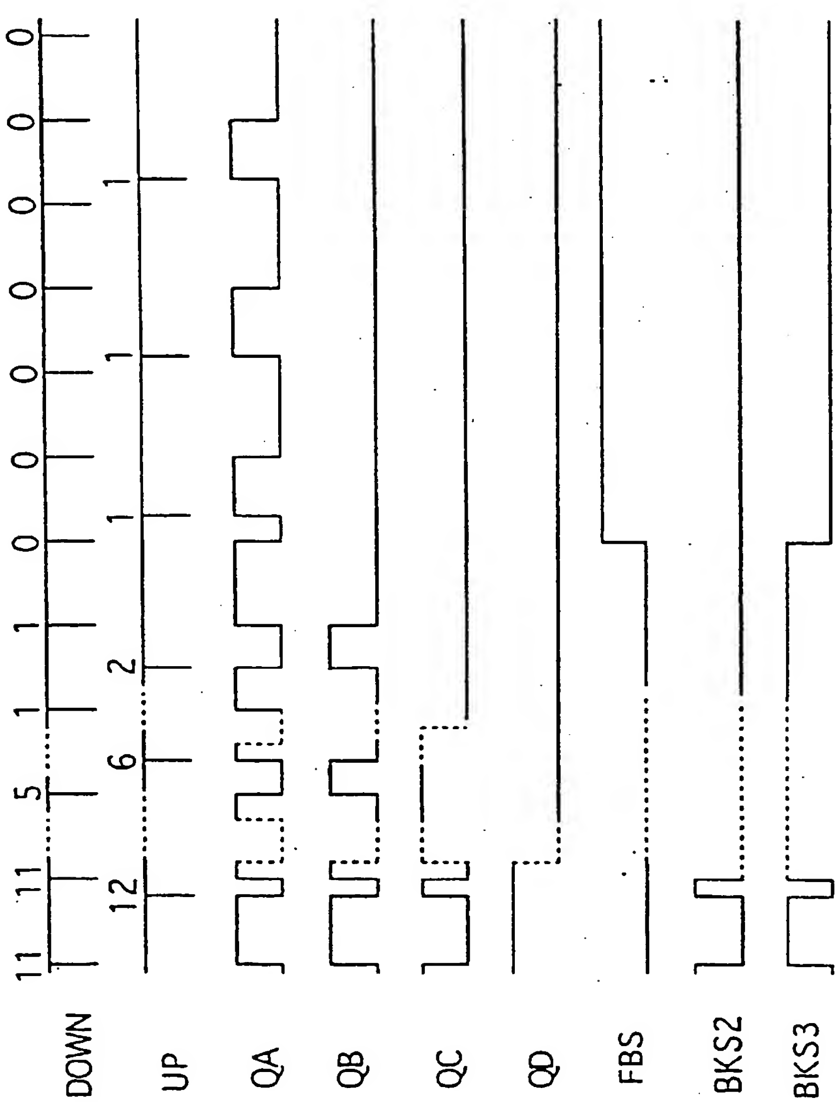
[FIG. 17]


INITIALIZING CIRCUIT
91
SR
22
21
RECTIFIER
20
23A
23
23C
53
61
FG1
BKS3
WAVEFORM SHAPER
201
BKS2
200
210
211
FBS
220
222
221
100
233
230
232
231
SR
LOAD
UP
DOWN
54
102
FG2
72
71
70
50
FG1
8Hz
64Hz
512Hz
1024Hz
52
51
51A
56
CRYSTAL OSCILLATOR
OSCILLATOR CIRCUIT
FREQUENCY DIVIDER
LOW-SPEED ROTATION DETECTOR

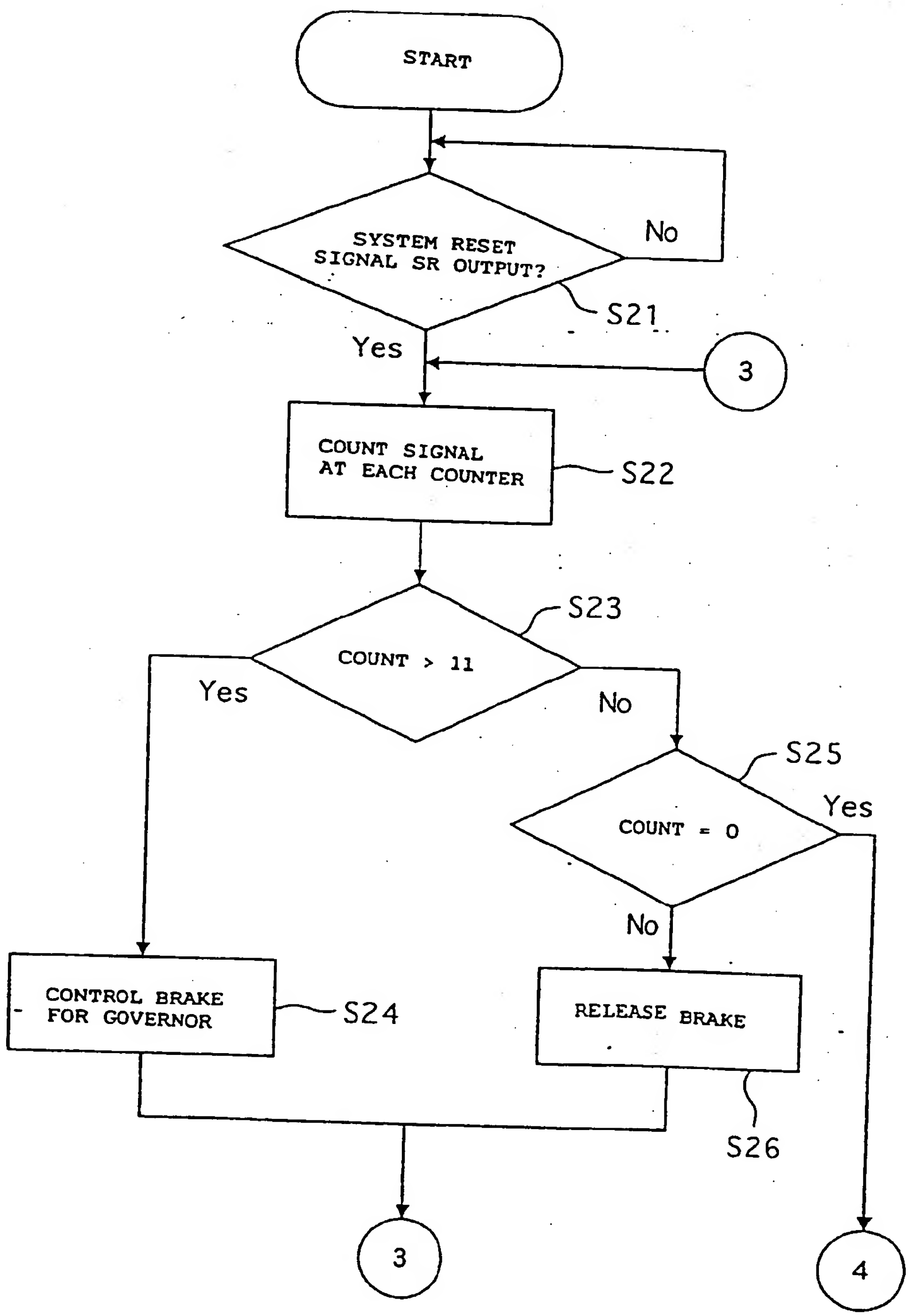
[FIG. 18]



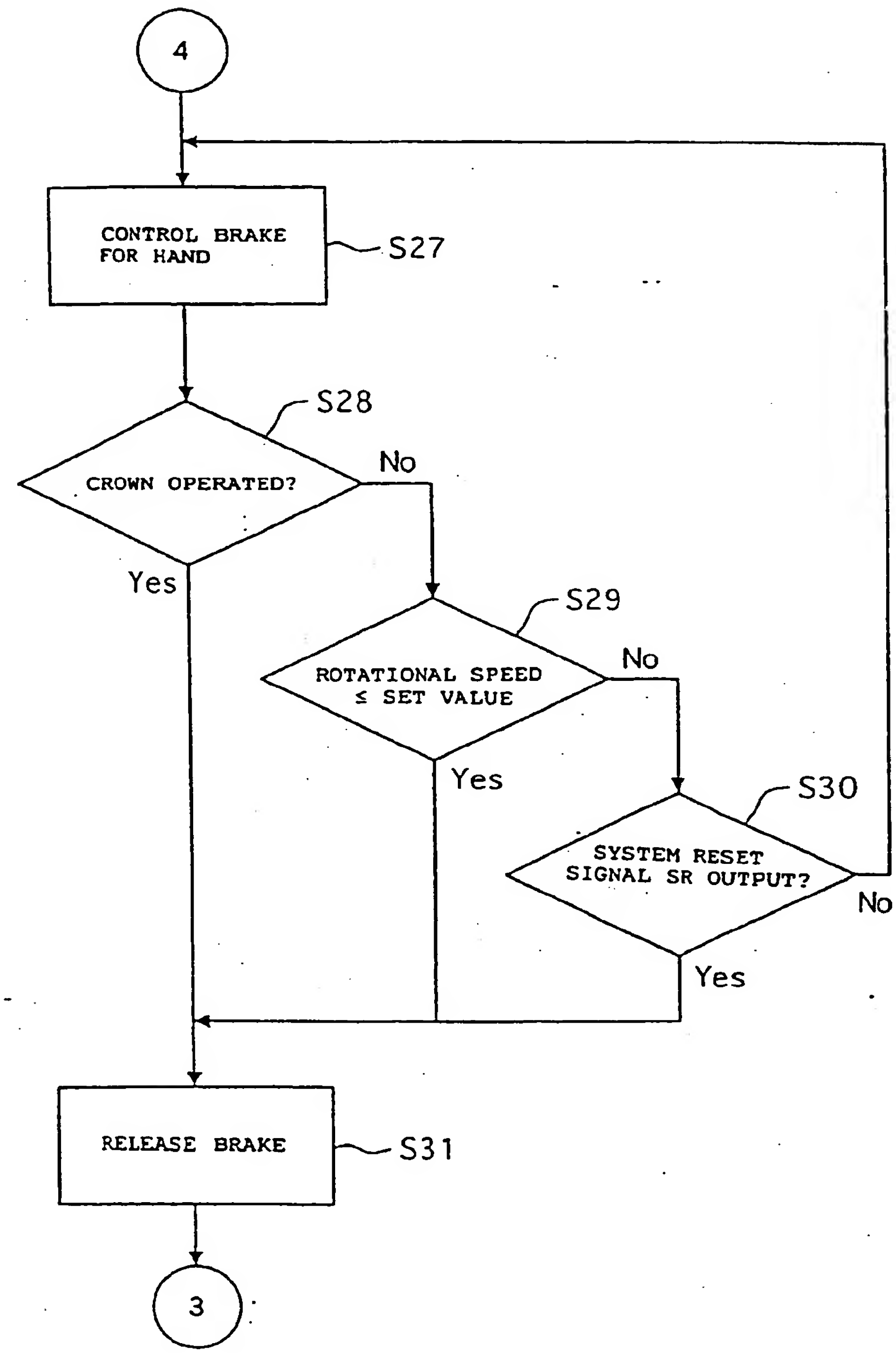
[FIG. 19]



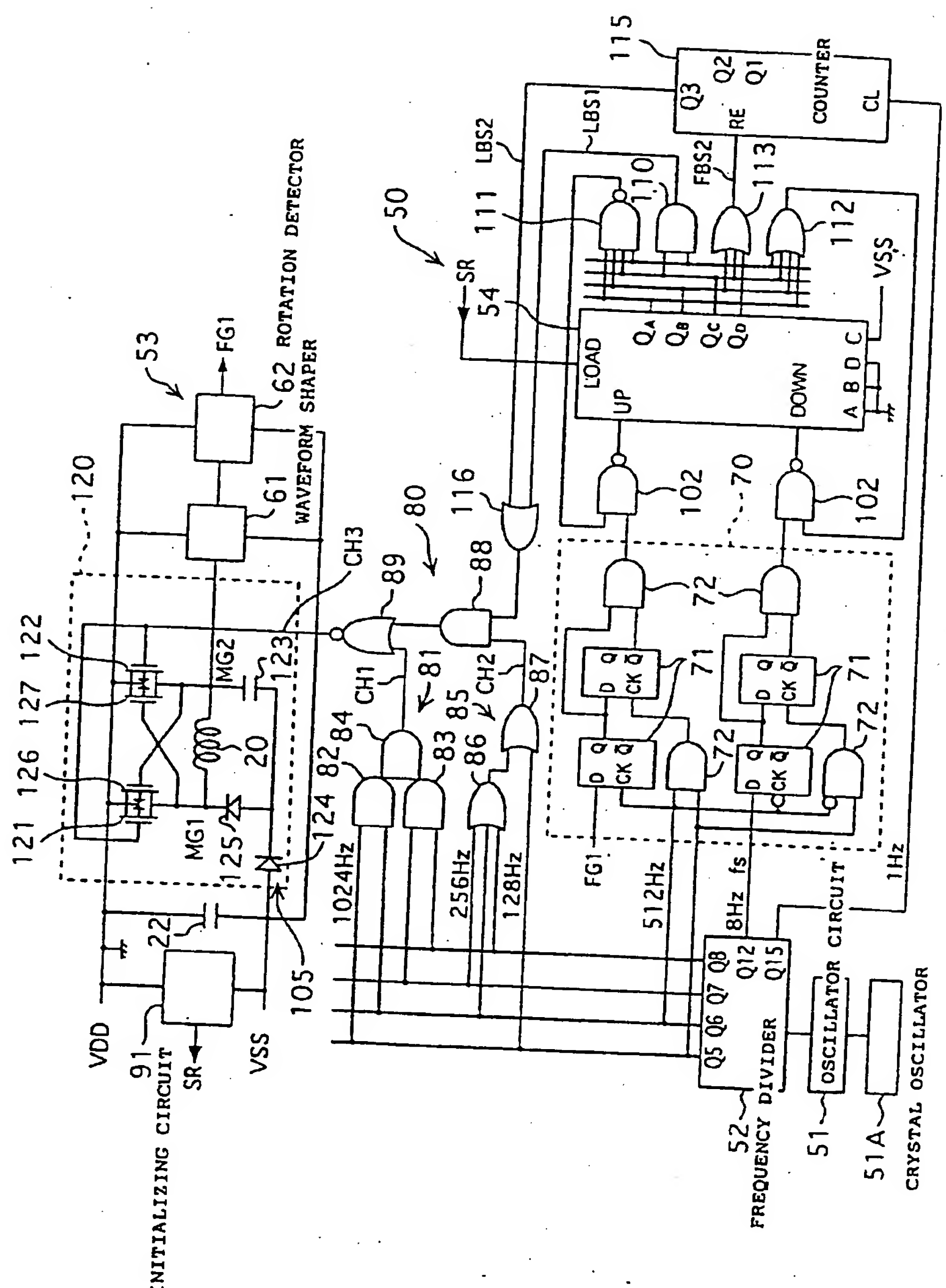
[FIG. 20]


START
SYSTEM RESET SIGNAL SR OUTPUT?
No
S21
Yes
3
COUNT SIGNAL AT EACH COUNTER
S22
S23
COUNT > 11
Yes
No
S25
Yes
COUNT = 0
No
CONTROL BRAKE FOR GOVERNOR
S24
RELEASE BRAKE
S26
3
4

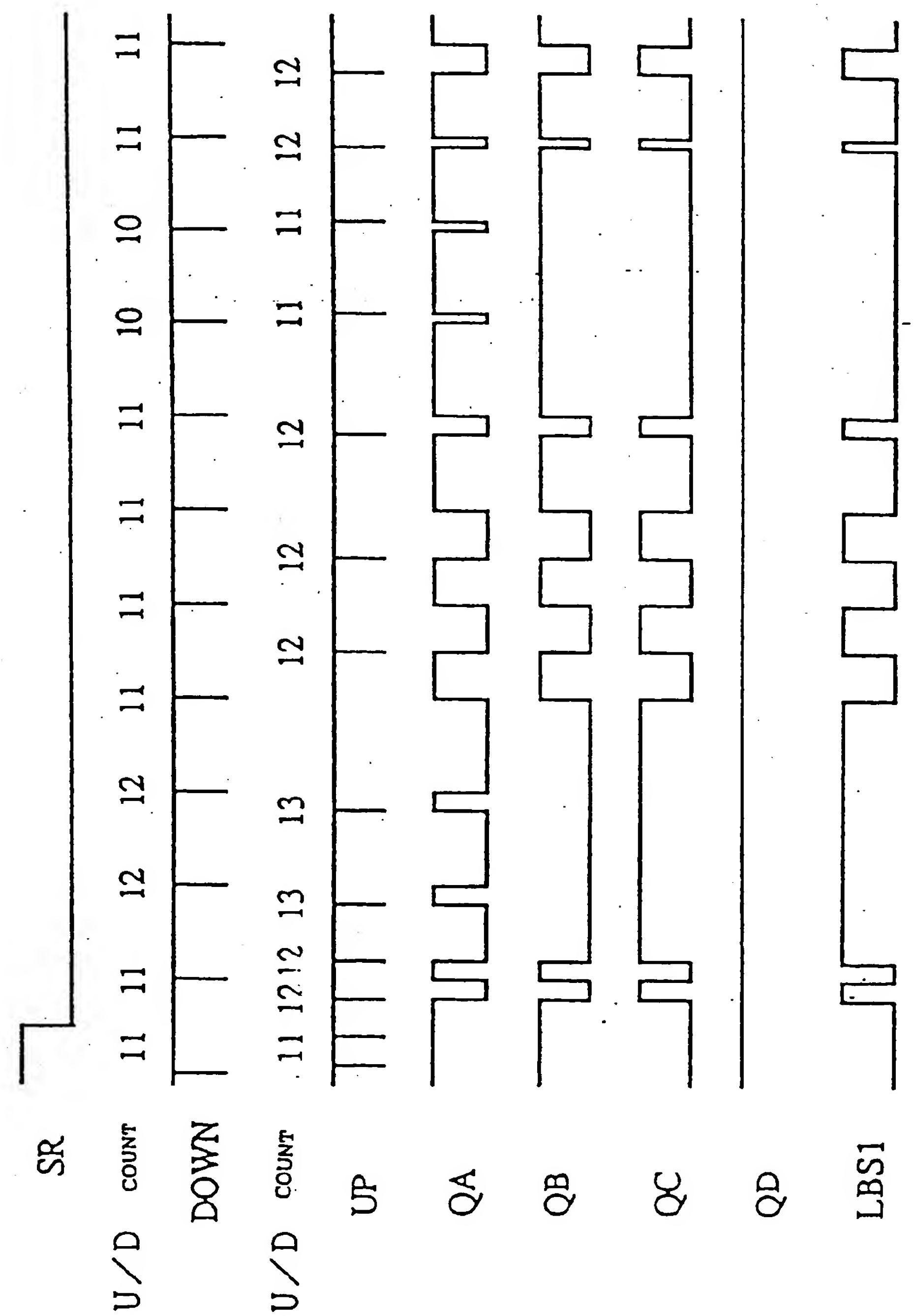
[FIG. 21]


4
CONTROL BRAKE FOR HAND
S27
S28
CROWN OPERATED?
No
Yes
S29
ROTATIONAL SPEED ≤ SET VALUE
No
Yes
S30
SYSTEM RESET SIGNAL SR OUTPUT?
No
Yes
RELEASE BRAKE
S31
3

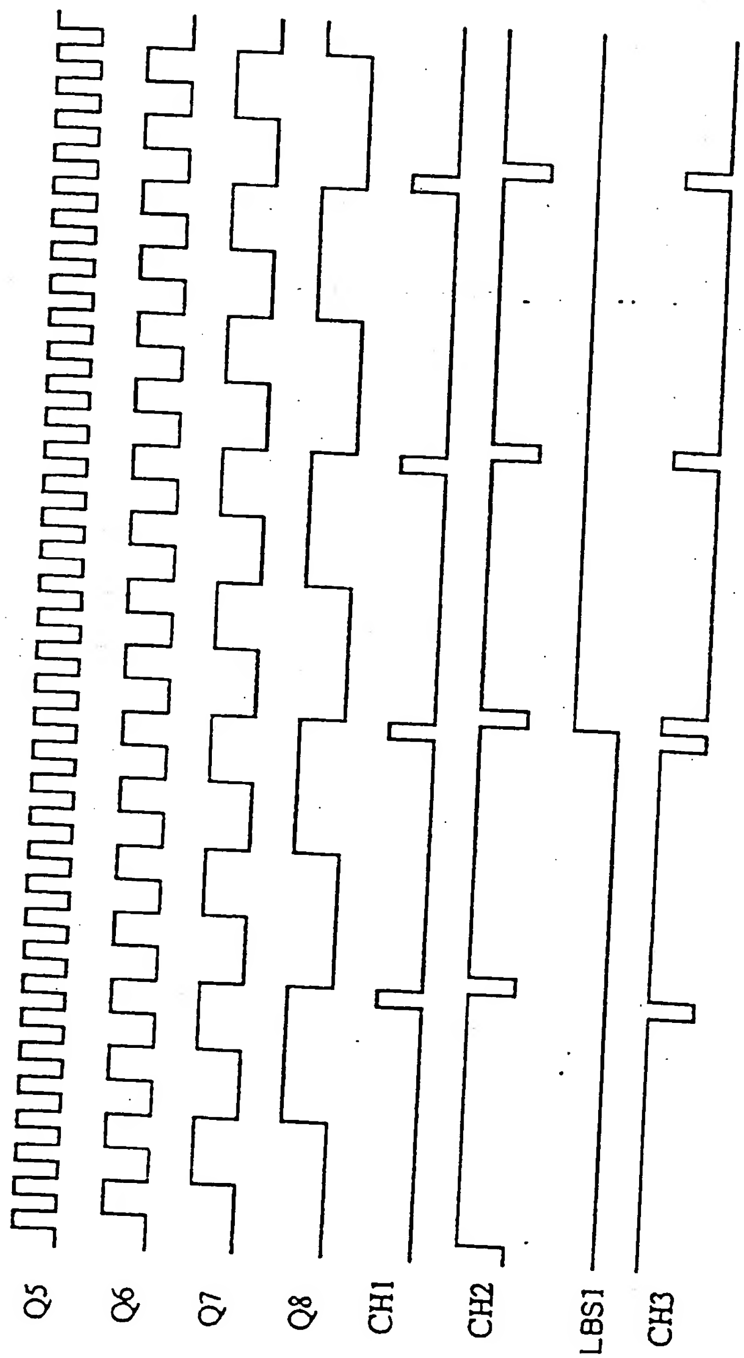
[FIG. 22]


INITIALIZING CIRCUIT
ROTATION DETECTOR
WAVEFORM SHAPER
FREQUENCY DIVIDER
OSCILLATOR CIRCUIT
CRYSTAL OSCILLATOR
COUNTER
VDD
VSS
SR
FG1
LOAD
UP
DOWN
1024Hz
256Hz
128Hz
512Hz
8Hz fs
1Hz
LBS1
LBS2
FBS2
CH1
CH2
CH3
MG1
MG2

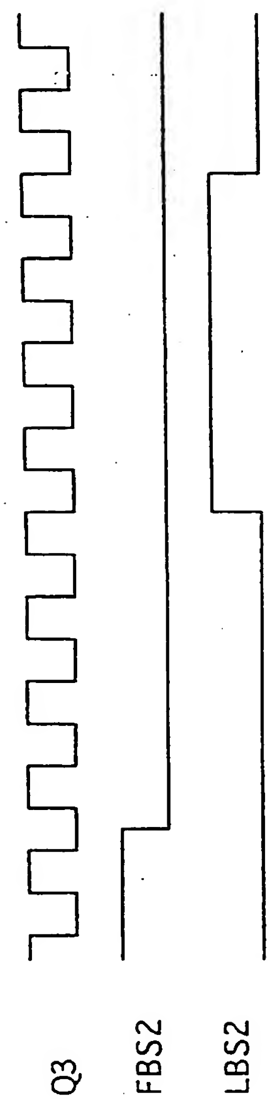
[FIG. 23]



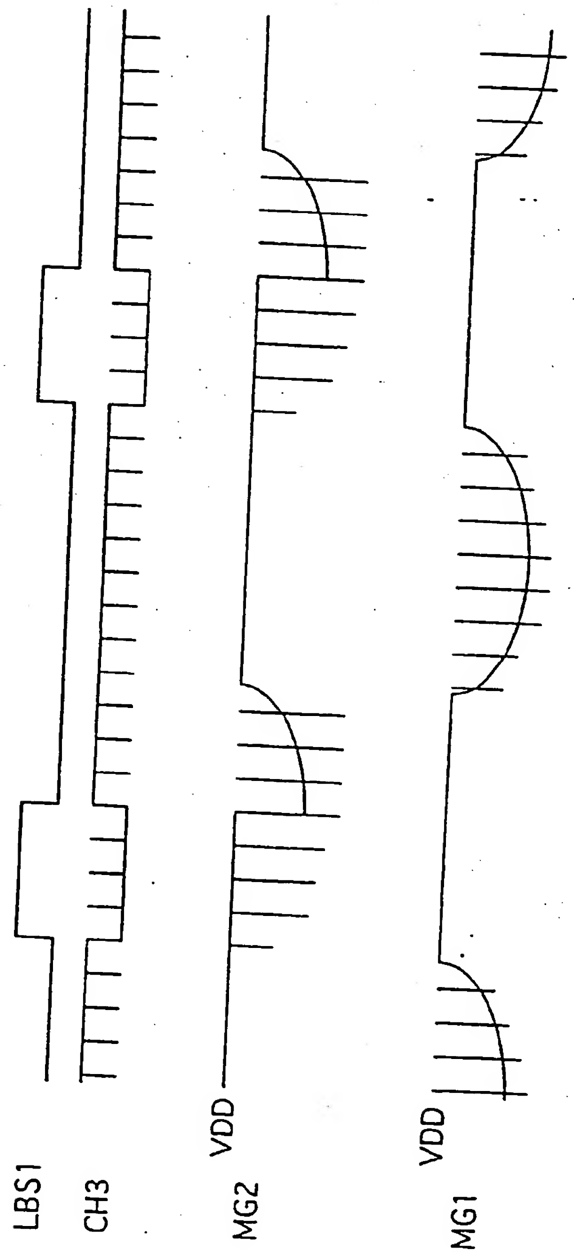
[FIG. 24]



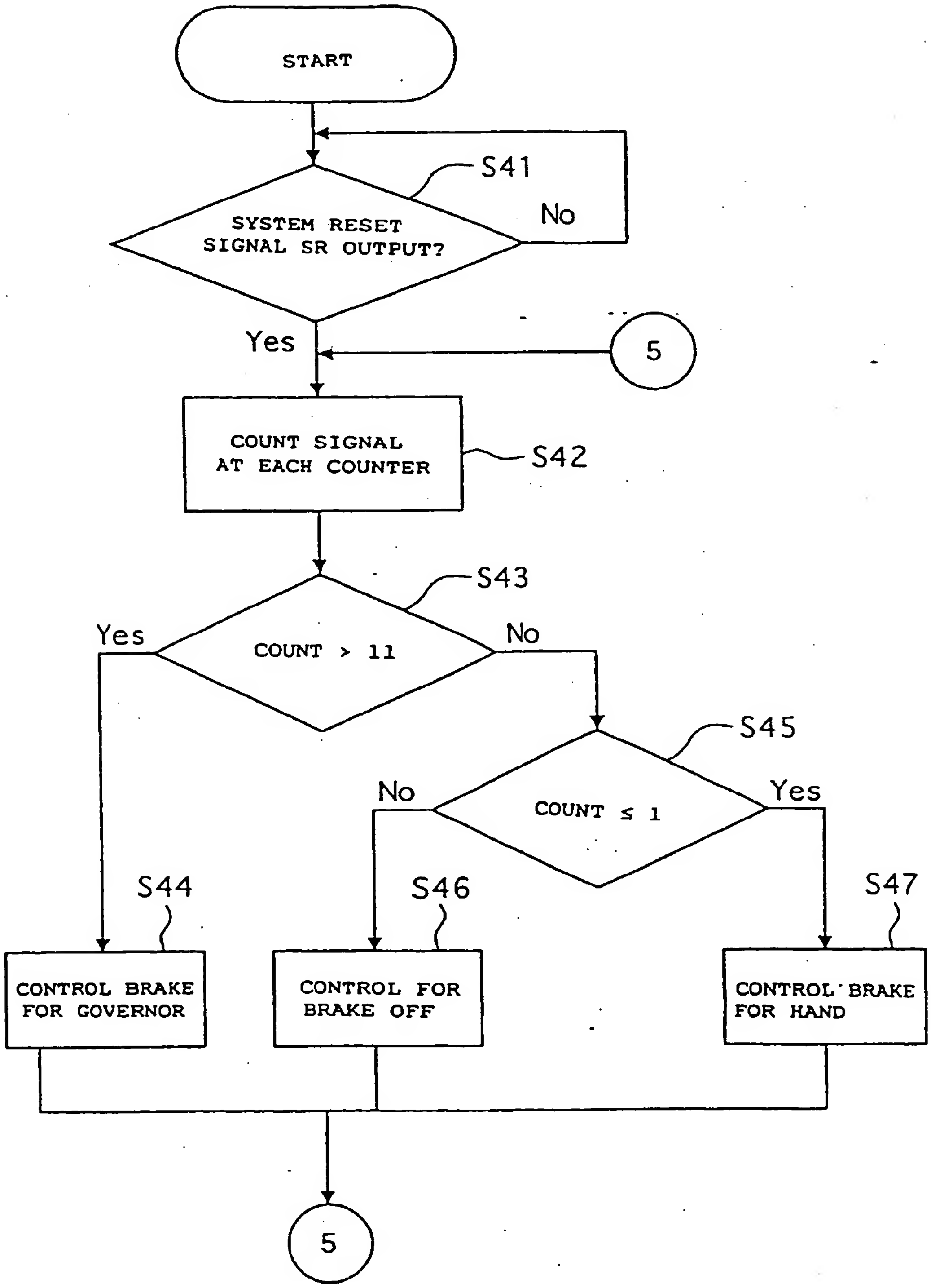
[FIG. 25]



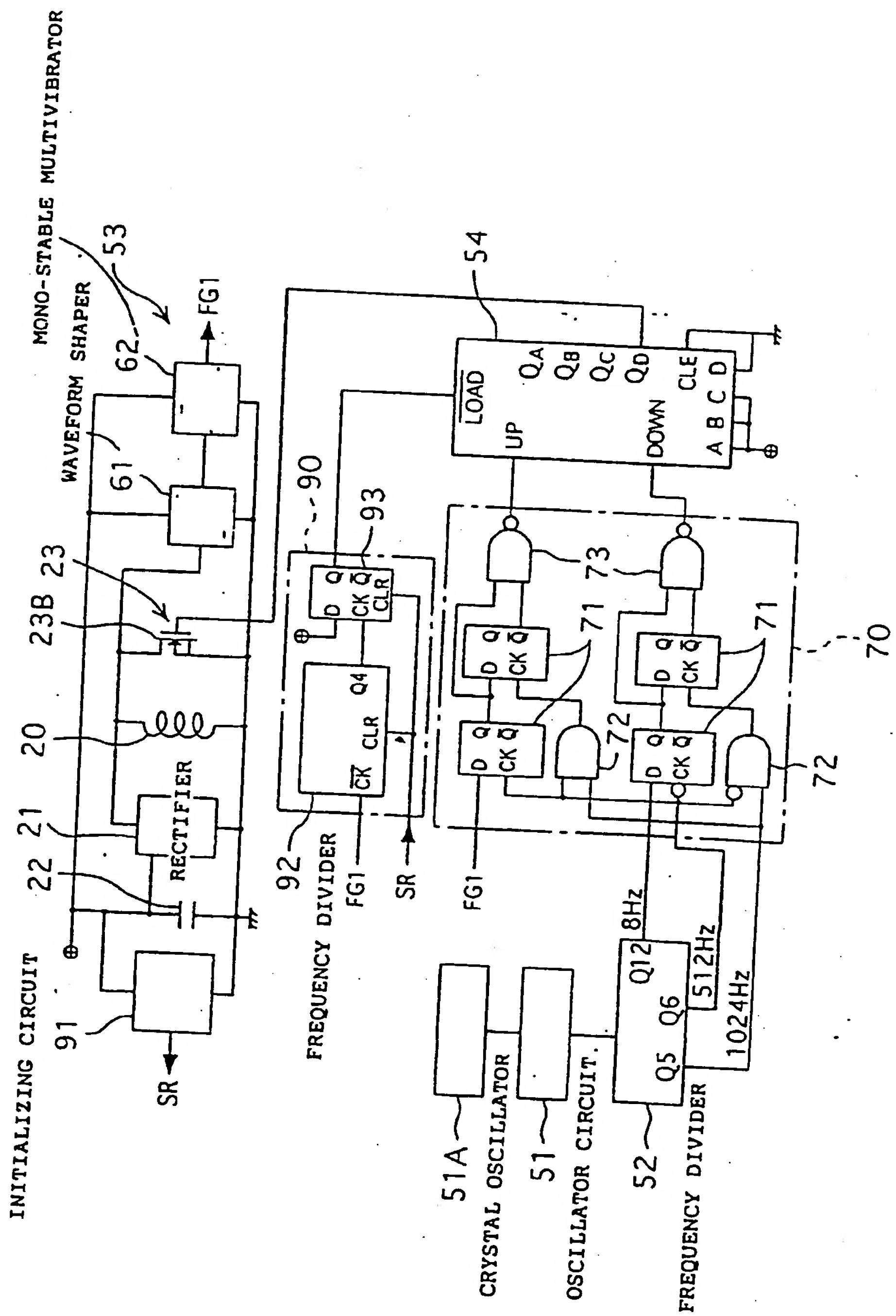
[FIG. 26]



[FIG. 27]


START
S41
SYSTEM RESET SIGNAL SR OUTPUT?
No
Yes
5
COUNT SIGNAL AT EACH COUNTER
S42
S43
COUNT > 11
Yes
No
S45
COUNT ≤ 1
No
Yes
S44
S46
S47
CONTROL BRAKE FOR GOVERNOR
CONTROL FOR BRAKE OFF
CONTROL BRAKE FOR HAND
5

[FIG. 28]


INITIALIZING CIRCUIT
91
SR
22
21
RECTIFIER
20
23B
23
WAVEFORM SHAPER
61
62
MONO-STABLE MULTIVIBRATOR
53
FG1
FREQUENCY DIVIDER
92
90
93
D Q
CK Q
CLR
CK CLR Q4
FG1
SR
54
LOAD
UP
DOWN
QA QB QC QD
CLE
A B C D
73
71
72
70
FG1
8Hz
512Hz
1024Hz
Q12
Q6
Q5
51A
CRYSTAL OSCILLATOR
51
OSCILLATOR CIRCUIT
52
FREQUENCY DIVIDER